PRESENTATION

OF

FUEL CELL POWER SYSTEMS

FOR

APOLLO APPLICATIONS PROGRAM

ALLIS-CHALMERS

FACILITY FORM 602

N70-72666
(ACCESSION NUMBER)

64
(PAGES)

CR-109424
(NASA CR OR TMX OR AD NUMBER)

(THRU)

None
(CODE)

(CATEGORY)

5.5.3.

PRESENTATION

OF

FUEL CELL POWER SYSTEMS

FOR

APOLLO APPLICATIONS PROGRAM

Document BD-1001

May 29, 1967

ALLIS-CHALMERS

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ALLIS-CHALMERS
AAP FUEL CELL SYSTEM

- 56 DAY FLIGHT SYSTEM NOW BEING DVT'D
- FLIGHT-QUALIFIED SYSTEMS AVAILABLE JULY 1968
- NO ADDITIONAL PROGRAM PERTURBATION REQUIRED FOR AAP-COMMAND & SERVICE MODULE RETROFIT
- PROVEN INTERCHANGEABILITY BY PREVIOUS NORTH AMERICAN AVIATION'S STUDY
- CAPABILITY IN PRESENT SYSTEM FOR 2500 HOURS FOR ADVANCED AAP REQUIREMENTS
- FULL STAFF & FACILITIES NOW IN OPERATION

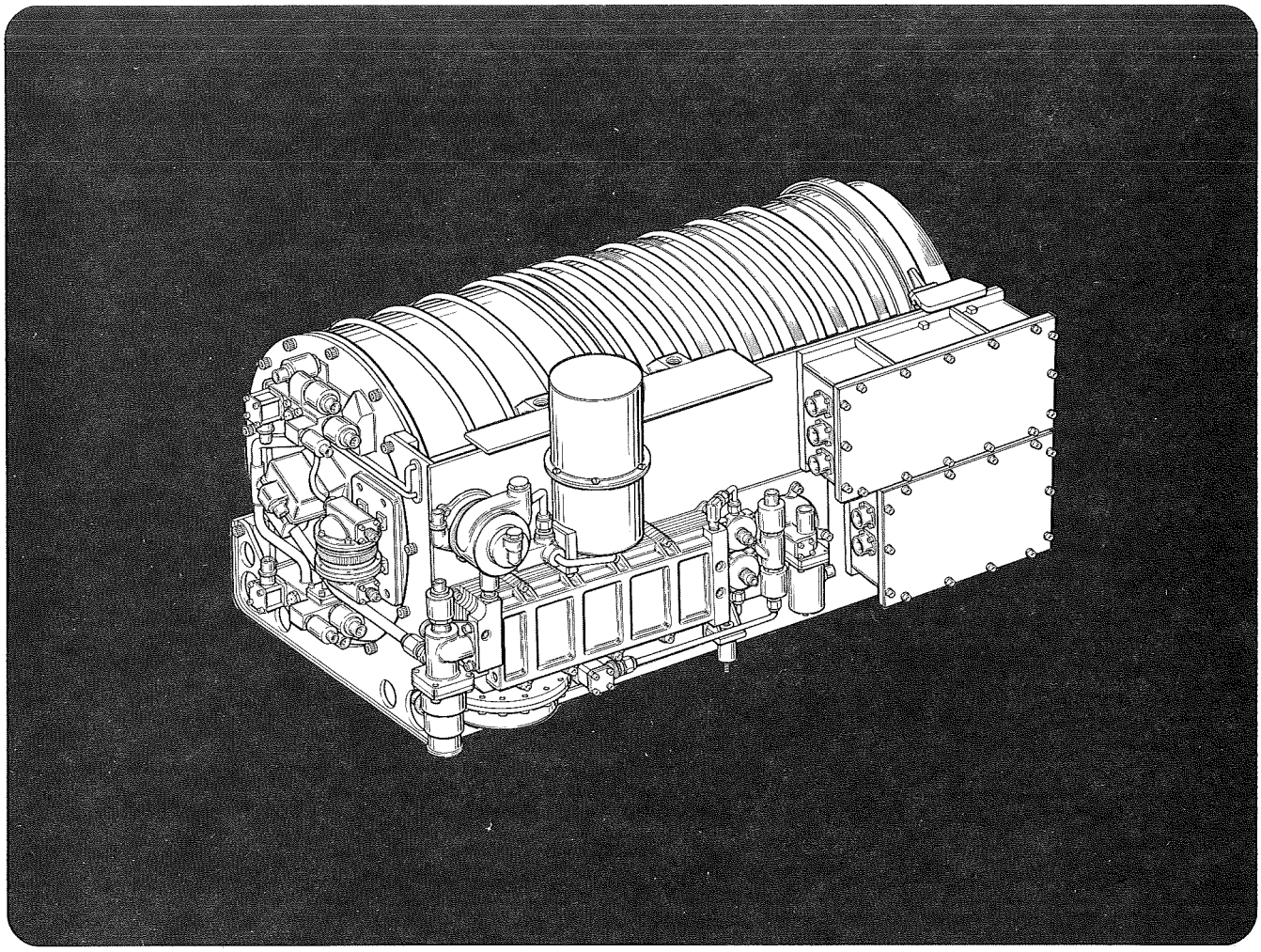
ALLIS-CHALMERS

RESEARCH DIVISION · MILWAUKEE, WIS.

FUEL CELL POWER FOR APOLLO APPLICATIONS

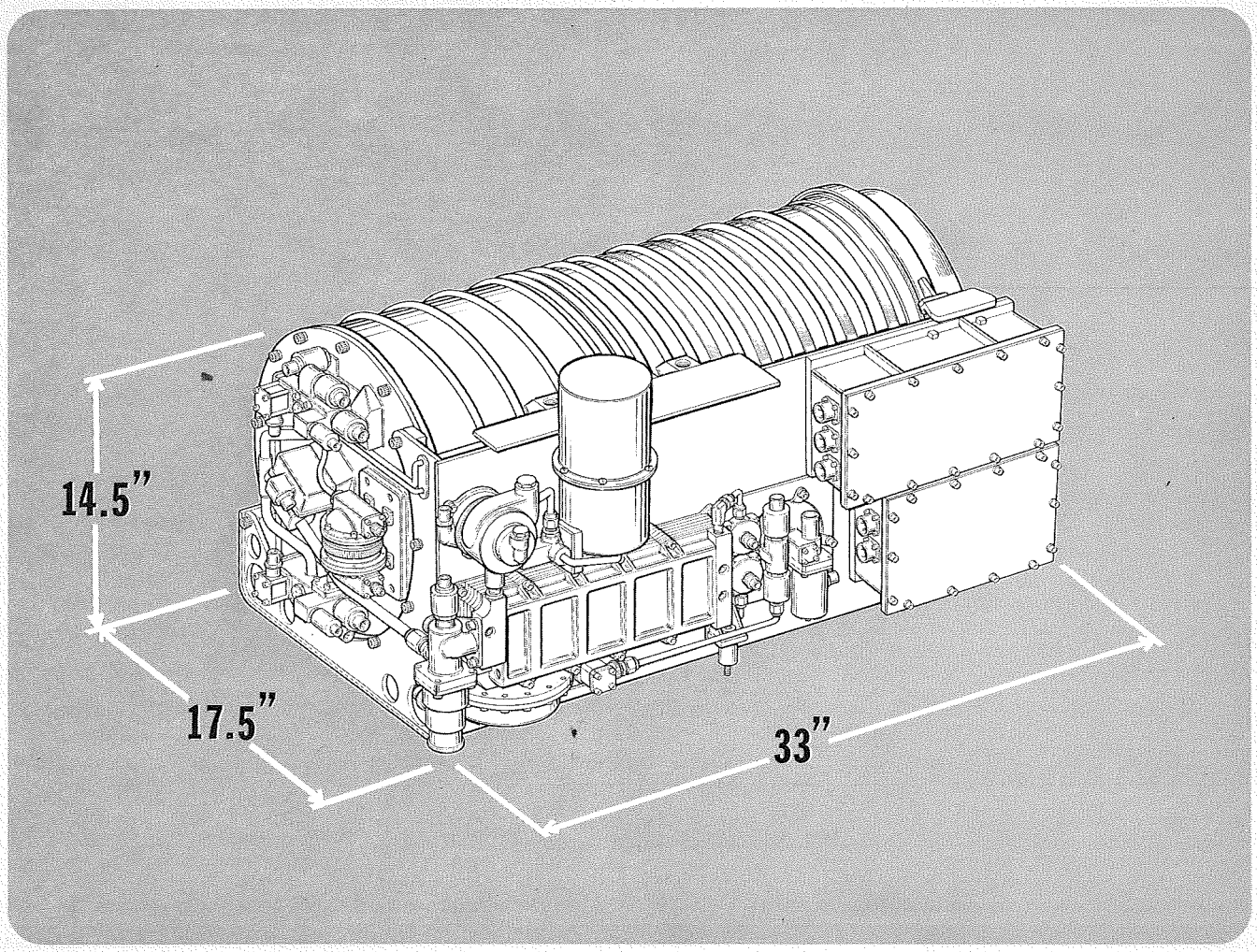
FUEL CELL POWER FOR APOLLO APPLICATIONS PROGRAM

- FUEL CELL DEVELOPMENT HISTORY
- FUEL CELL MODULE DESCRIPTION
- AAP ELECTRICAL POWER SYSTEM PERFORMANCE
- CSM RETROFIT ANALYSIS
- PROGRAM SUPPORT CAPABILITIES
- SUMMARY



NASA 2KW FUEL CELL MODULE

MODULE SIZE

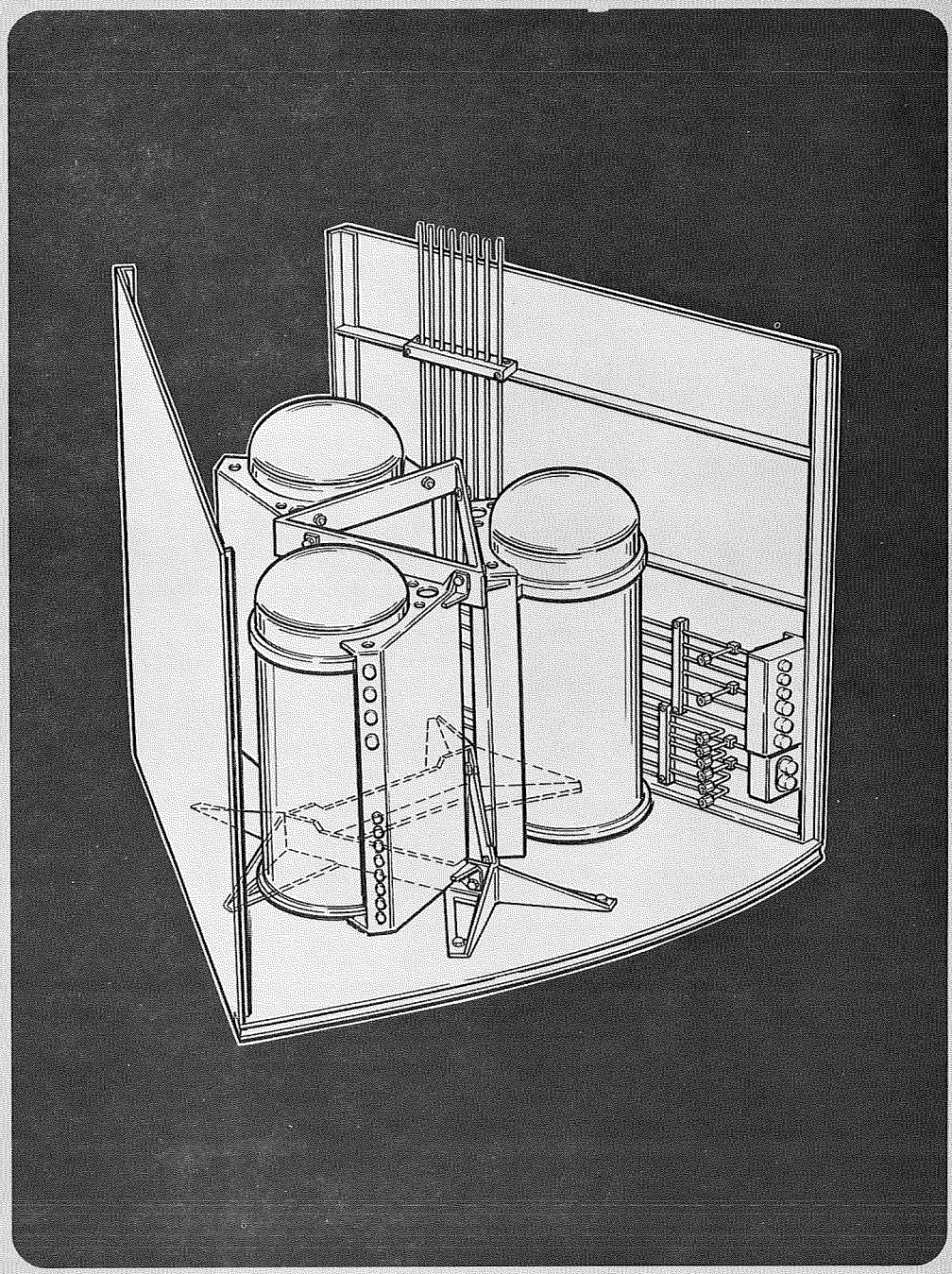


NOTE:

FUEL CELL MODULE CAN BE MOUNTED IN ANY PLANE.

CSM RETROFIT ANALYSIS

PHYSICAL INTERFACE



FUEL CELL INSTALLATION IN SM BAY IV

ALLIS-CHALMERS

RESEARCH DIVISION · MILWAUKEE, WIS.

FUEL CELL POWER FOR APOLLO APPLICATIONS

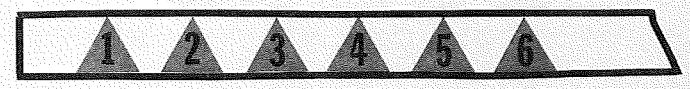
HISTORY

'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68

COMMERCIAL

1 INITIATE RESEARCH
2 TRACTOR PROTOTYPE
3 GOLF CART
4 FORK LIFT
5 STAR-I SUBMARINE
6 FC FOR LABS AND SCHOOLS

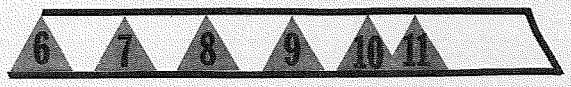
MILITARY



1 H_2 - O_2, ARMY
2 ENERGY DEPOT, AEC
3 5 KW HYDROCARBON, ARMY
4 O_2 GENERATOR, NAVY
5 2 KW SUBMERSIBLE, NAVY
6 600 W HYDRAZINE, ARMY

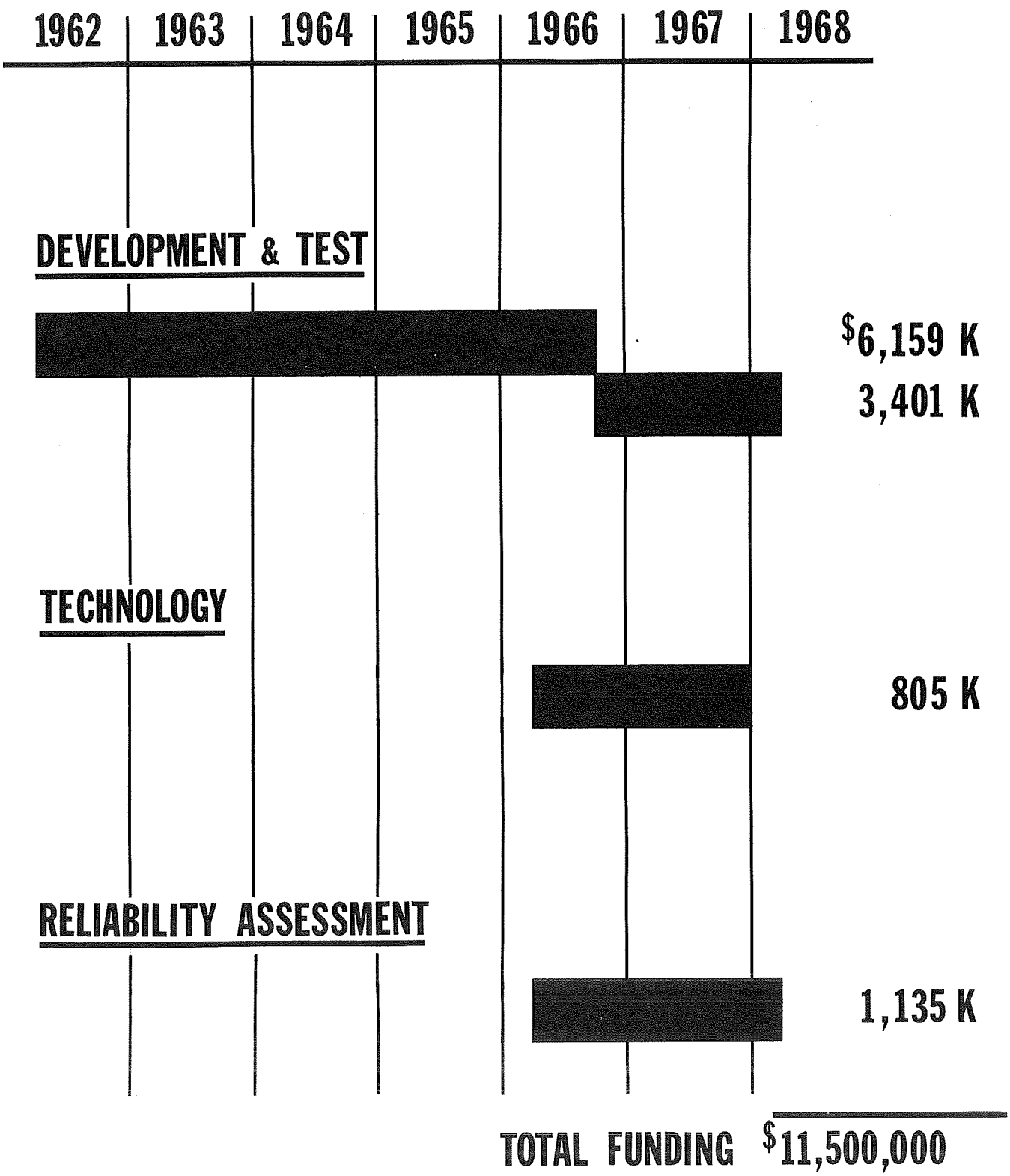
AEROSPACE

AIR FORCE PROGRAMS ———

NASA PROGRAMS ——— 

1 ZERO - G
2 50 W QUALIFICATION
3 DEL. 200 W
4 1000 HR TEST OF 200 W
5 FLIGHT TEST - 200 W
6 INITIAL DEV.
7 1 KW F C
8 START DEV. 2 KW F C
9 DEM. 1800 HR LIFE
10 2500 HR DEV. PROGRAM
11 DVT FOR 2 KW F C

NASA FUNDING HISTORY



NASA PROGRAM OBJECTIVES

DEVELOPMENT & TEST

- GENERAL - DEVELOP CLOSED CYCLE 2 KW H_2-O_2 FUEL CELL SYSTEM FOR SPACE MISSIONS TO 90 DAYS.
- SPECIFIC - COMPLETE DEVELOPMENT OF 1500 HR FUEL CELL SYSTEM FOR DVT TESTING BY NASA & A-C. DELIVER 5 DVT SYSTEMS TO NASA, MSC. CONTINUE DESIGN EFFORT TOWARDS A 2500 HR SYSTEM.

TECHNOLOGY

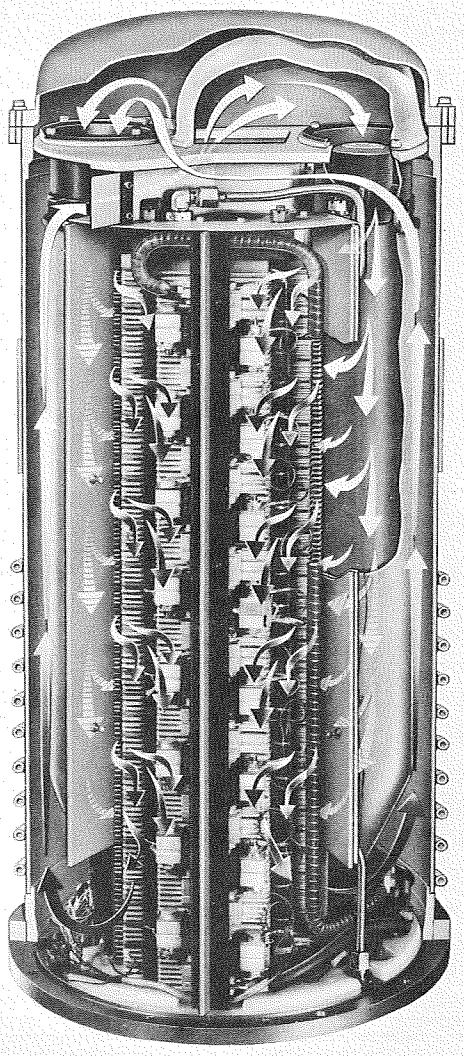
- GENERAL - PERFORM ANALYSIS & CONDUCT TESTS TO DEVELOP TECHNOLOGY FOR LONG LIFE, HIGH PERFORMANCE & RELIABLE FUEL CELL SYSTEMS FOR SPACE APPLICATIONS.
- SPECIFIC - PERFORM STUDIES & CONDUCT TESTS ON ELECTRODES, MATRICES, ELECTROLYTES, SCALE-UP EFFECTS, PURGING, COOLING TECHNIQUES & OPERATING VARIABLES.

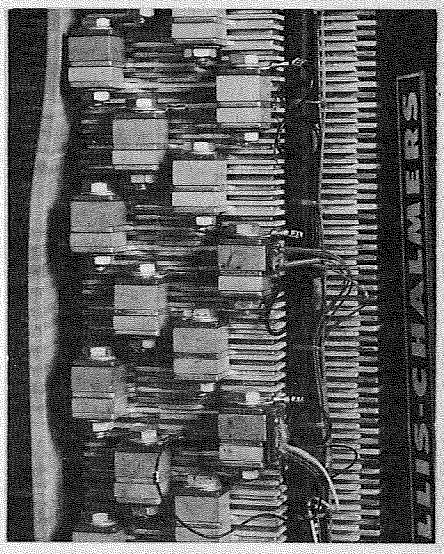
RELIABILITY ASSESSMENT

- GENERAL - EVALUATION OF 2 KW FUEL CELL PERFORMANCE CAPABILITY UNDER BOTH NORMAL & OVERSTRESS CONDITIONS, TO ESTABLISH OPERATING LIMITATIONS FOR RELIABLE OPERATION.
- SPECIFIC - PERFORM ENDURANCE & OFF-LIMITS TESTS TO ASSESS RELIABILITY.

FUEL CELL MODULE DESCRIPTION

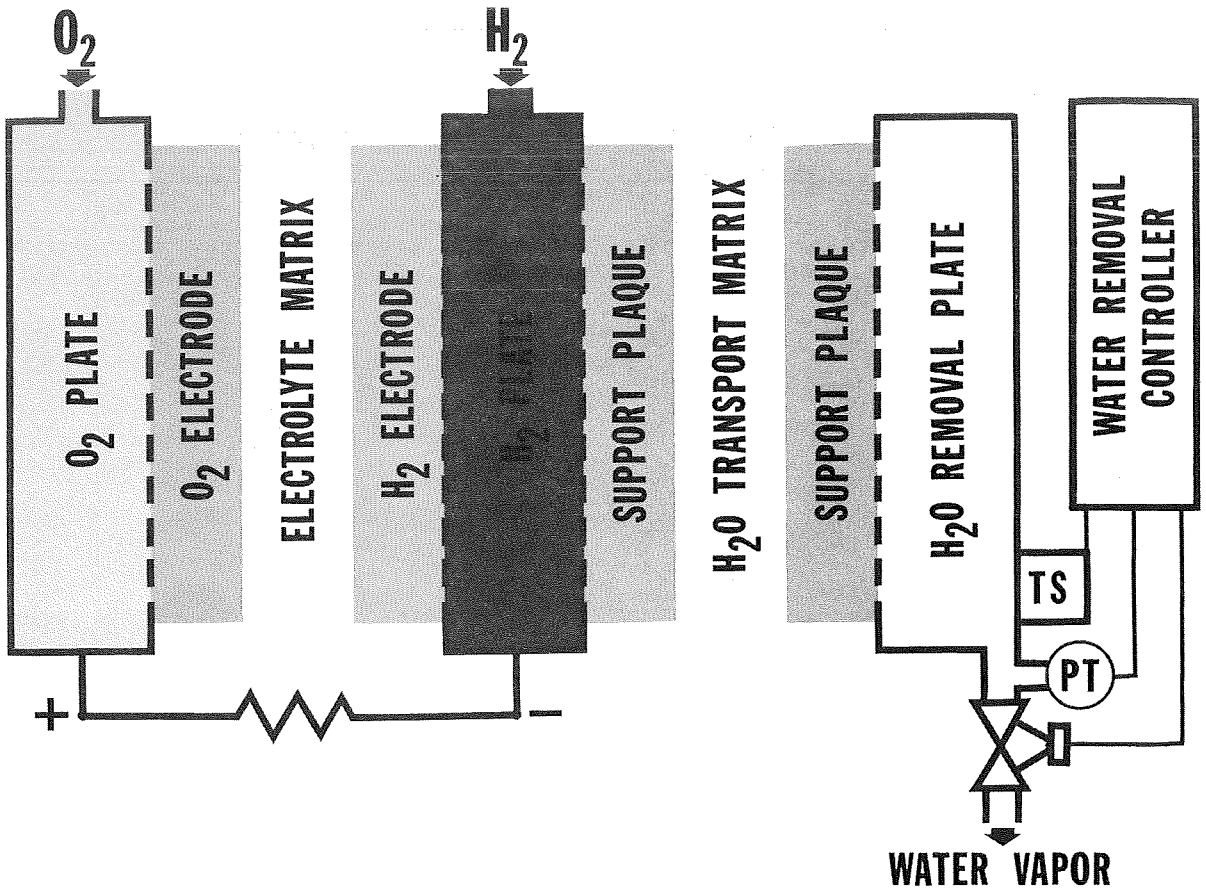
FUEL CELL STACK & CANISTER

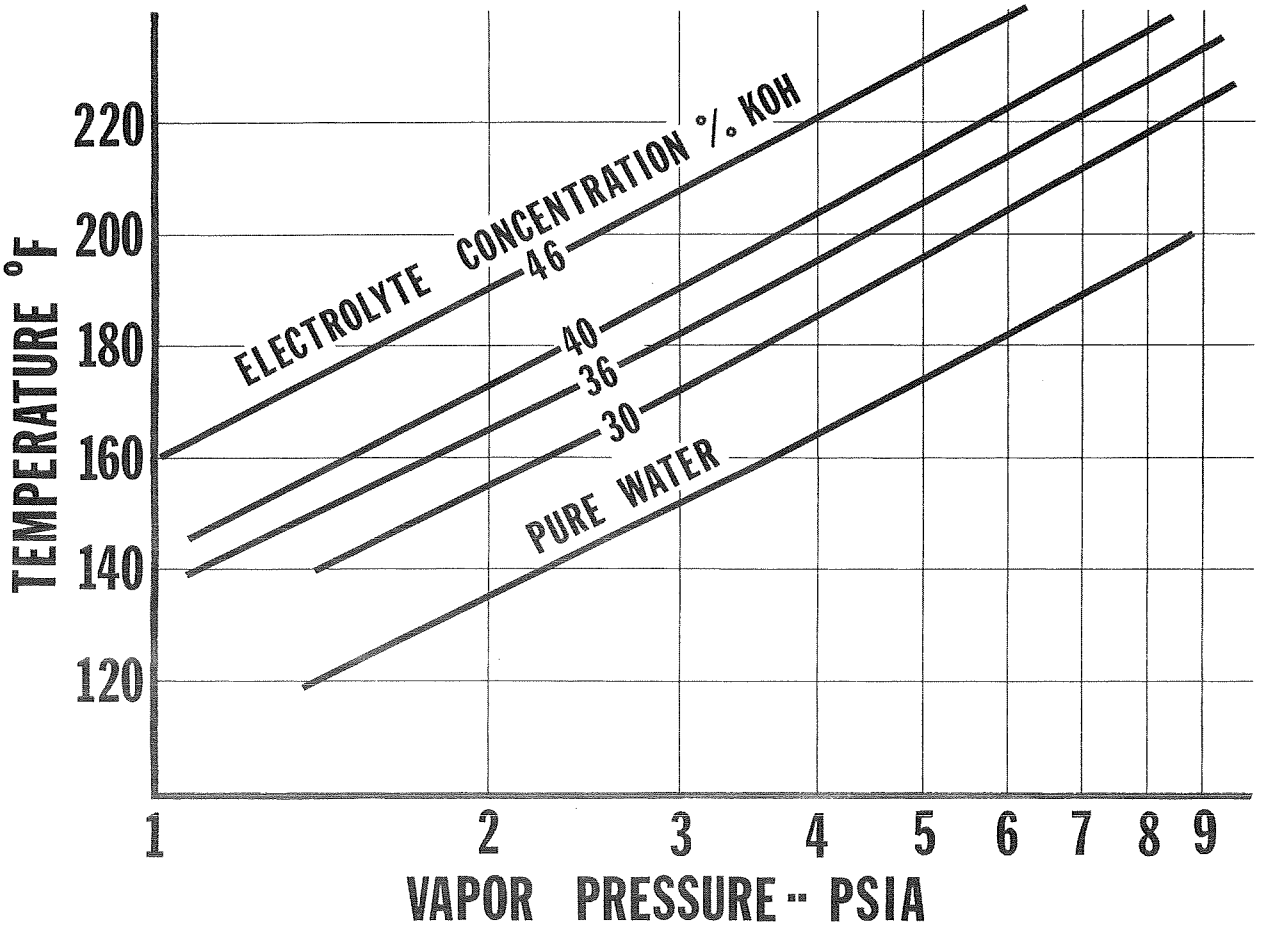




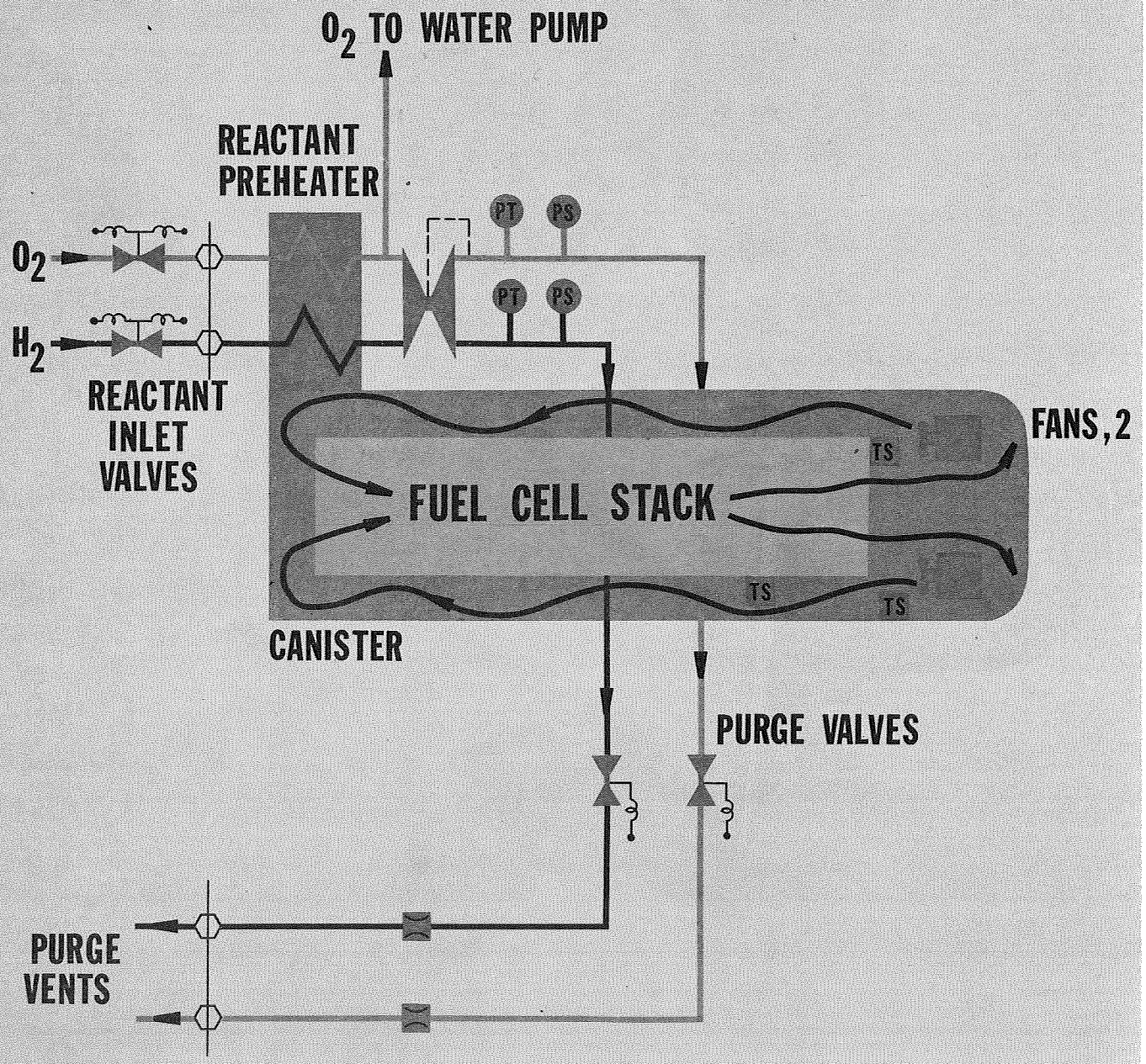
STACK DETAIL

FUEL CELL THEORY

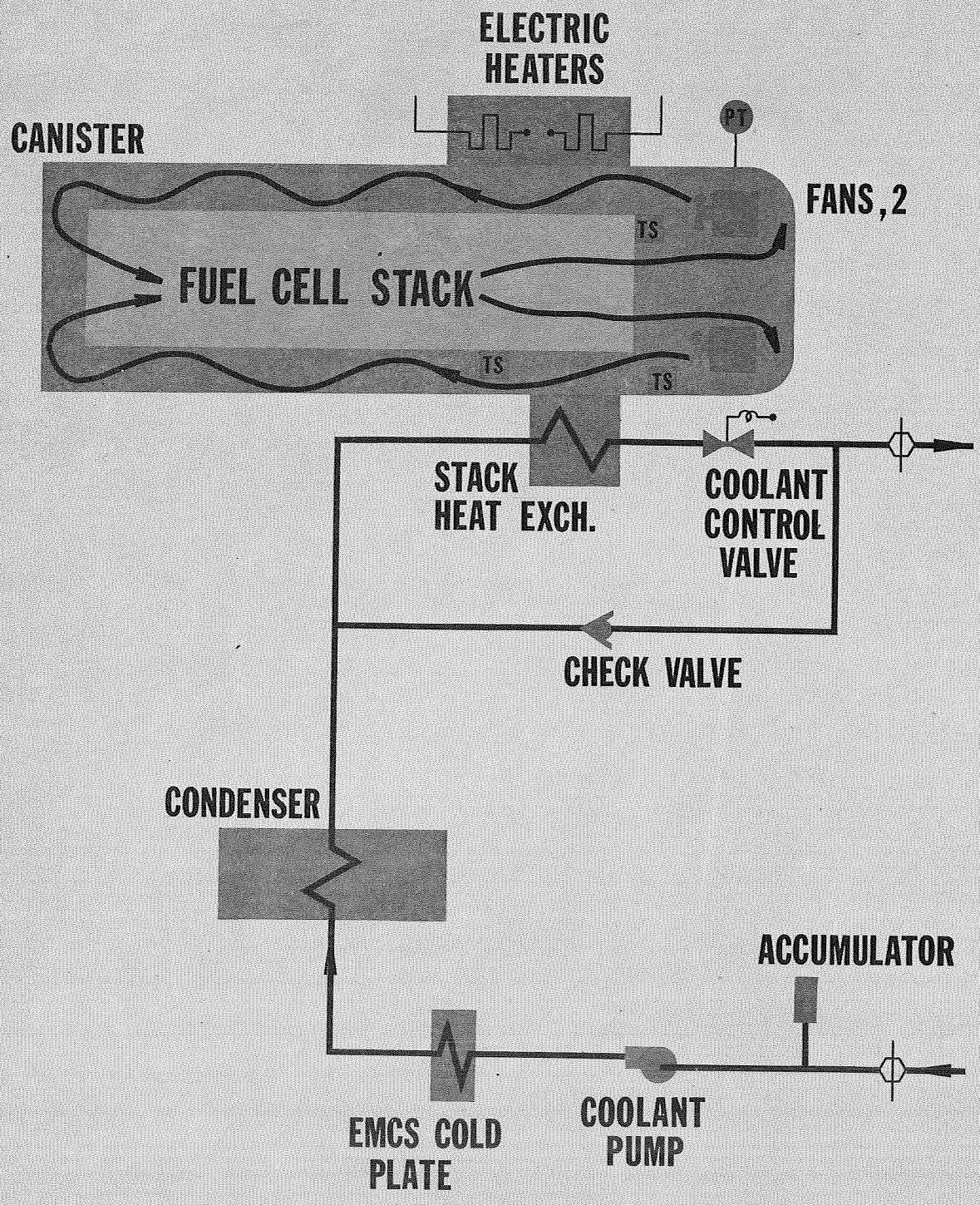




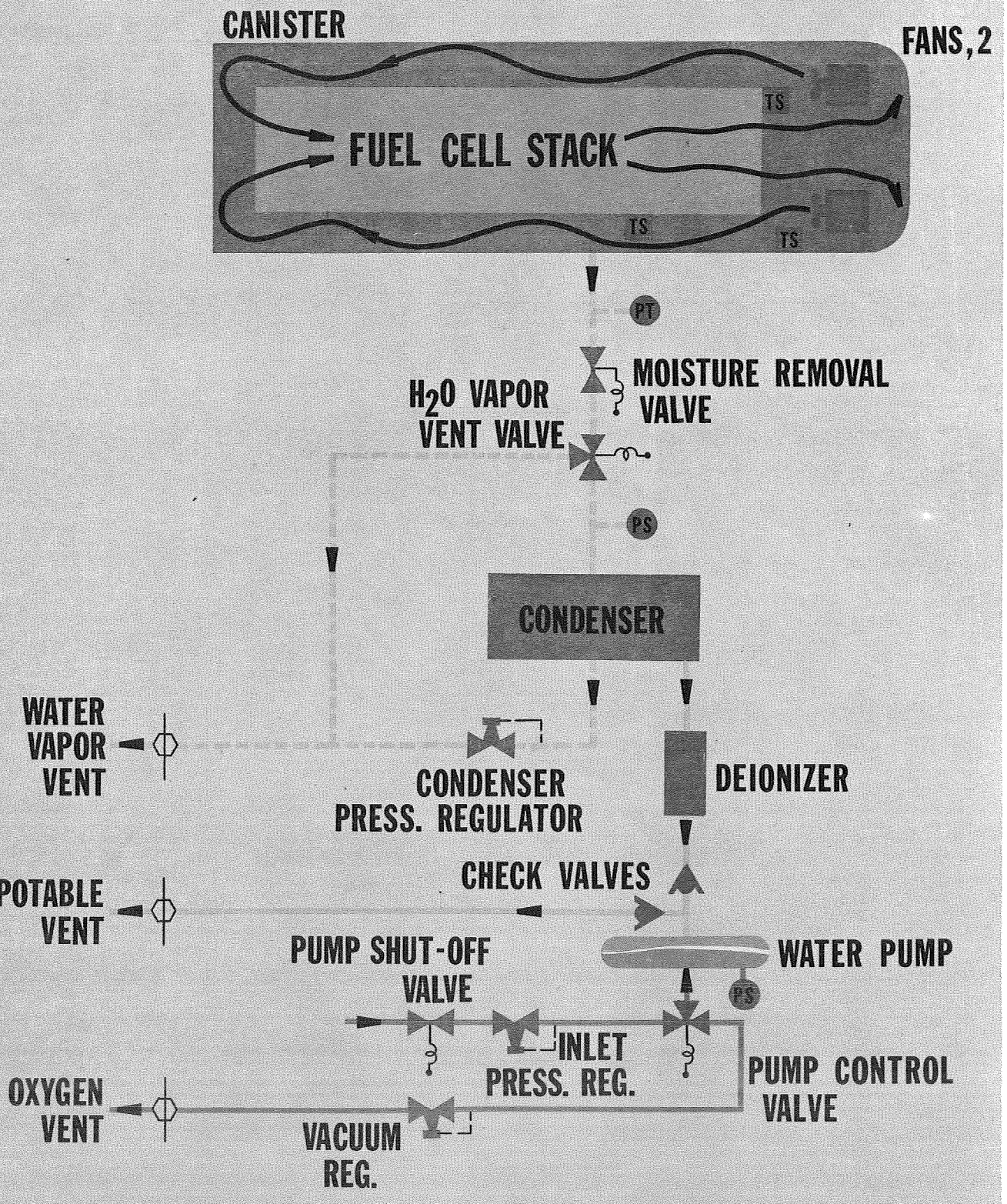
REACTANT CONTROL SUBSYSTEM



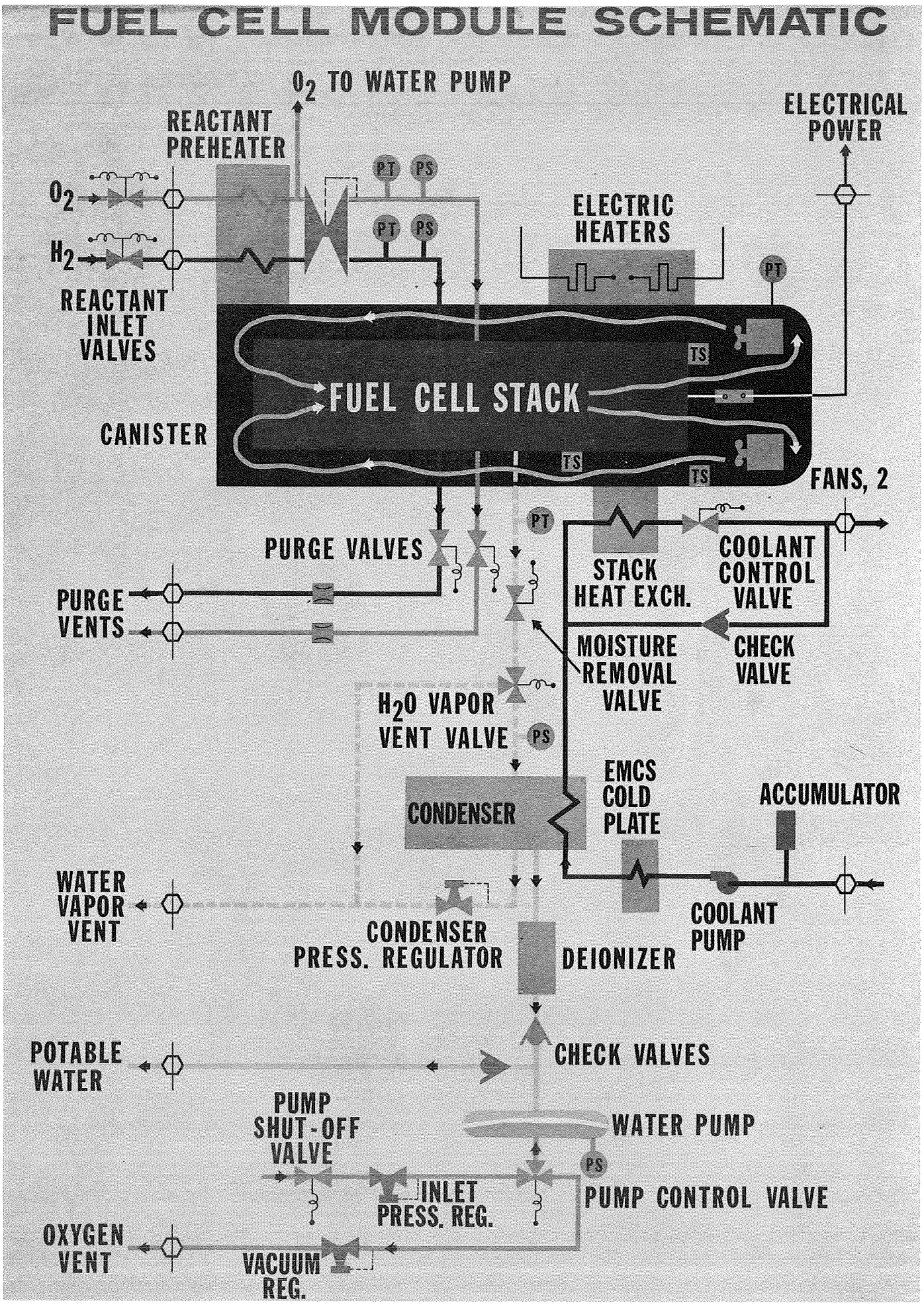
THERMAL CONTROL SUBSYSTEM



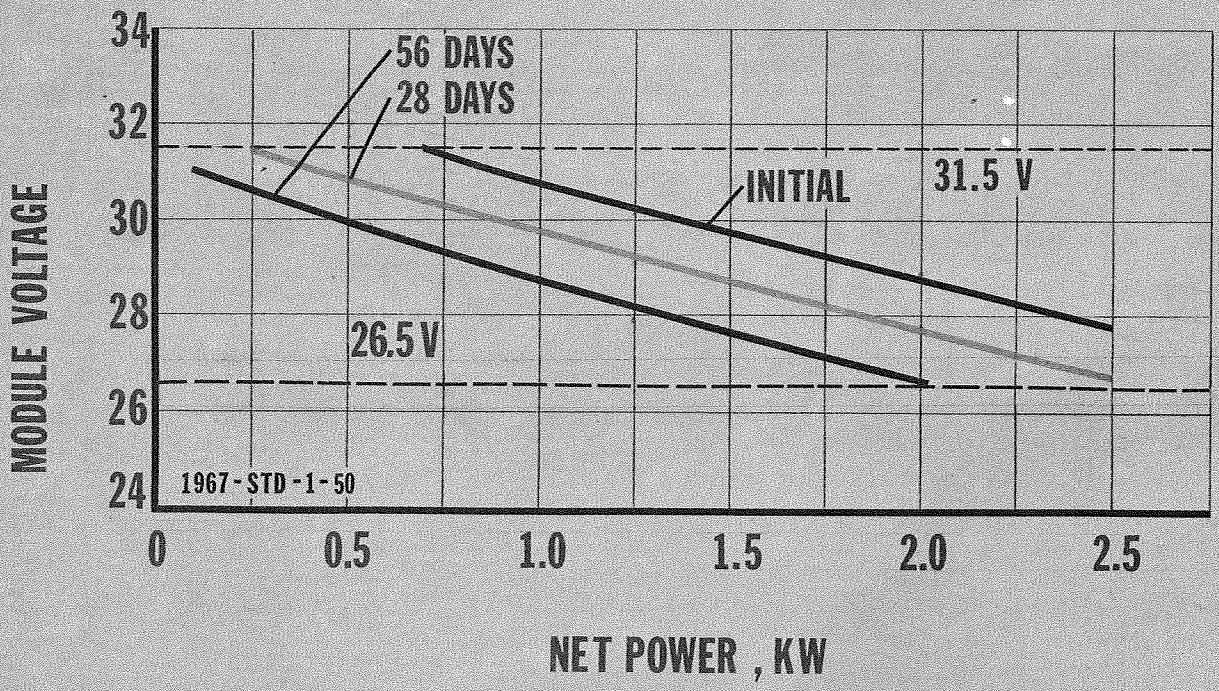
MOISTURE CONTROL SUBSYSTEM



FUEL CELL MODULE SCHEMATIC



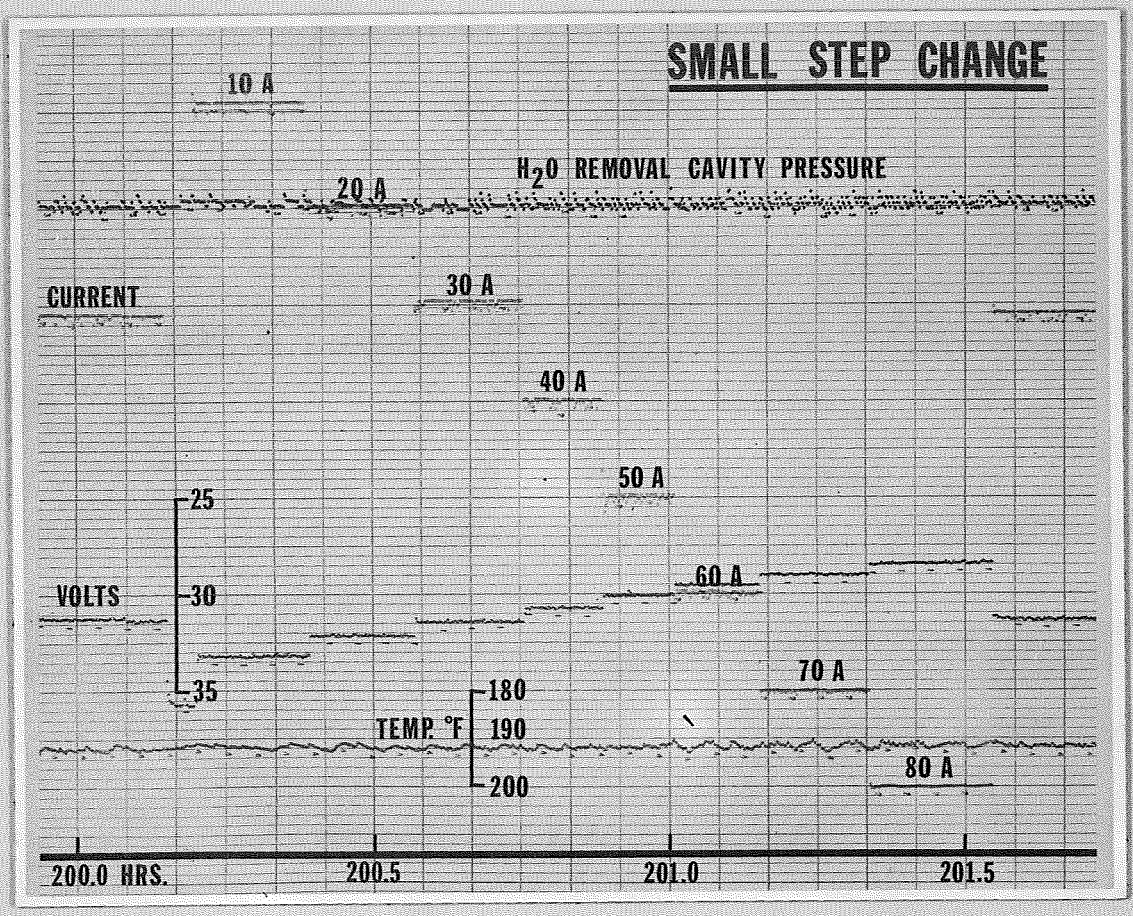
MODULE ELECTRICAL PERFORMANCE

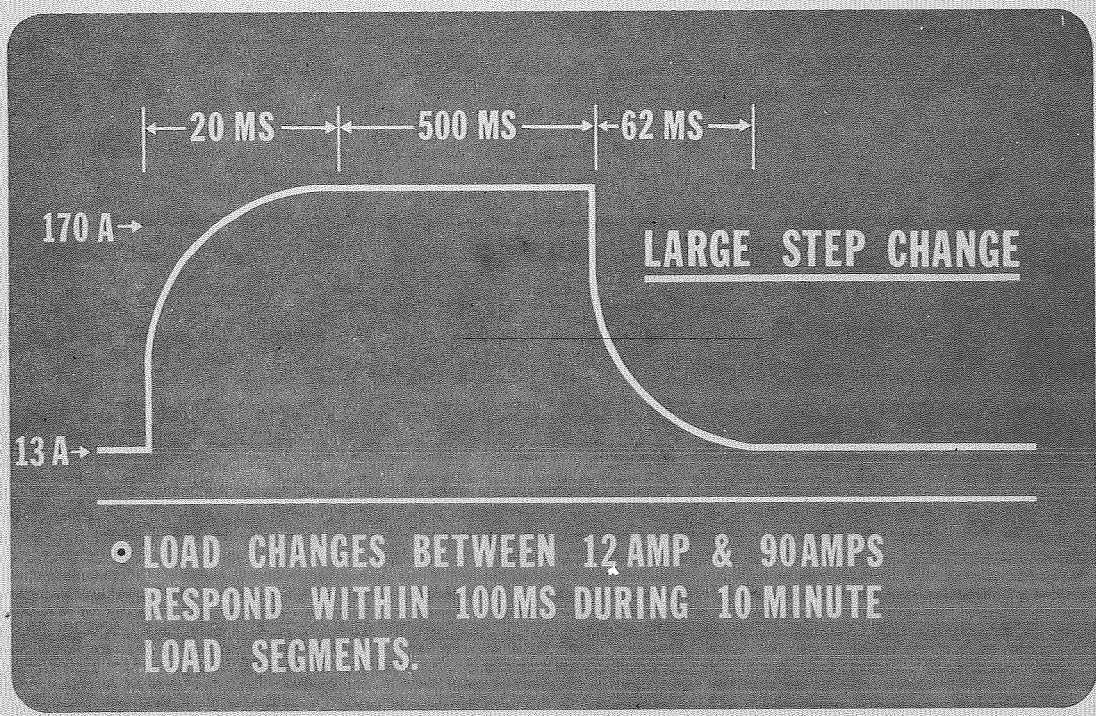


NOTE:

- 50 WATTS PARASITIC POWER
- SINGLE MODULE , 32 SECTIONS

MODULE TRANSIENT RESPONSE





- LOAD CHANGES BETWEEN 12 AMP & 90 AMPS RESPOND WITHIN 100 MS DURING 10 MINUTE LOAD SEGMENTS.

MODULE
TRANSIENT RESPONSE

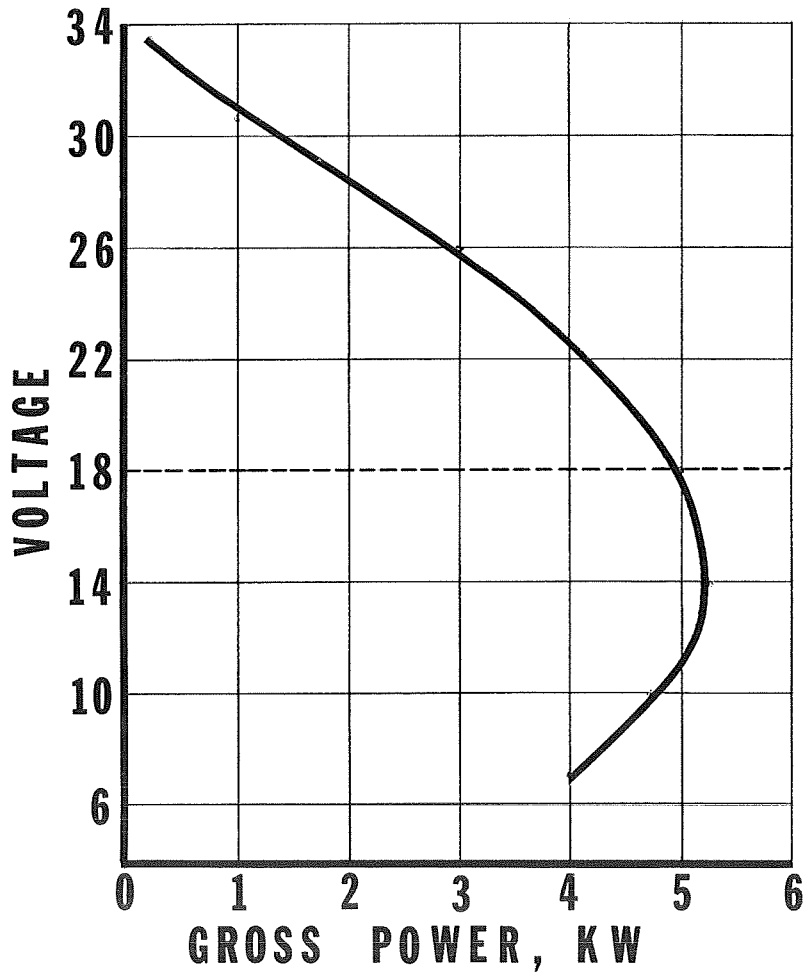
SIGNIFICANCE

- CAN SWITCH INSTANTANEOUSLY BETWEEN MAXIMUM & MINIMUM SPACECRAFT POWER LIMITS.
- REDUCED ASTRONAUT POWER MANAGEMENT REQUIREMENTS.
- REDUCED PEAKING BATTERY REQUIRMENTS FOR VOLTAGE REGULATION.
- HIGHER RELIABILITY DUE TO LESS DEPENDENCE ON BATTERY/CHARGER SYSTEM.

MODULE OVERLOAD PERFORMANCE

TEST RESULTS

LOAD LEVEL AMPERES	KW	DURATION, MINUTES	NO. OF OCCURENCES
100–200	2.5–4.5	5.0	21
201–250	4.5–4.8	2.0	7
251–350	4.8–5.0	1.0	20
351–450	5.0–3.0	0.25	10
			TOTAL 58



OVERLOAD PERFORMANCE

SIGNIFICANCE

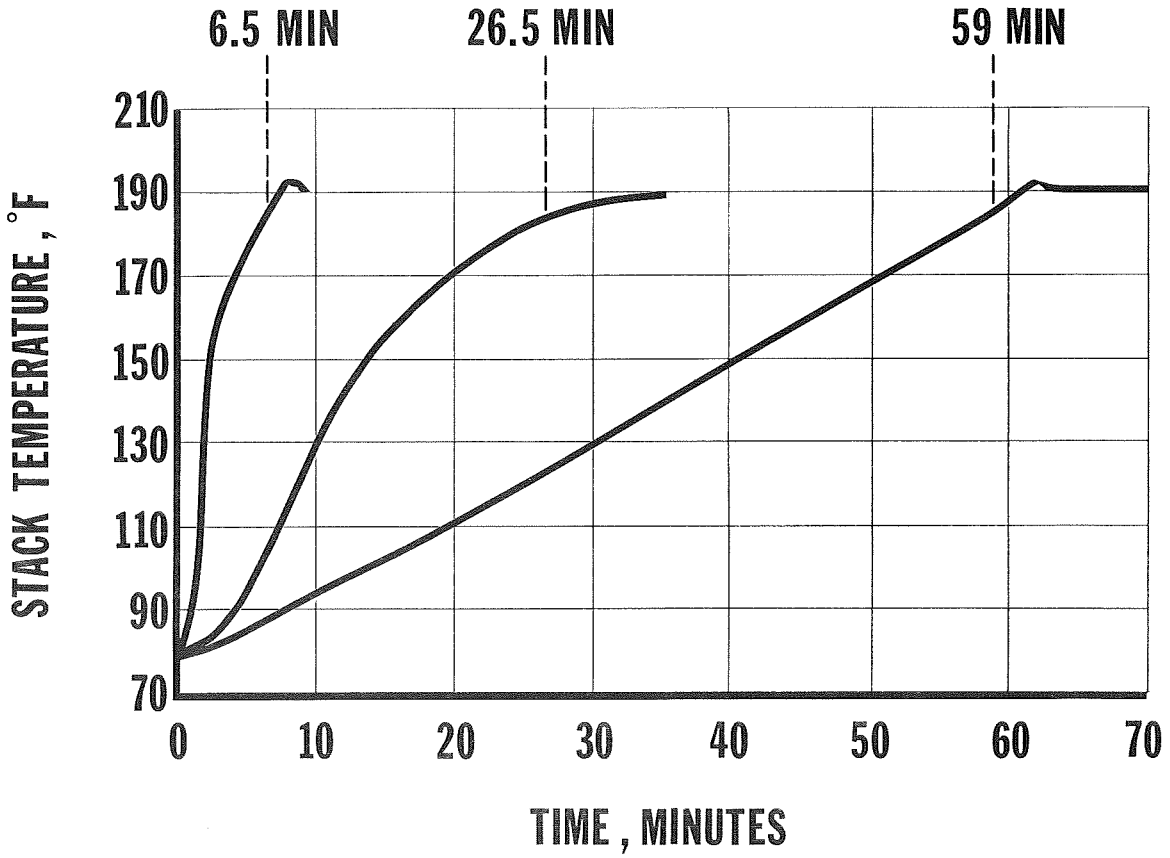
- REDUCES REQUIREMENTS FOR PEAKING BATTERIES

- HIGH CREW SAFETY RELIABILITY

BOOTSTRAP CAPABILITY

TEST RESULTS

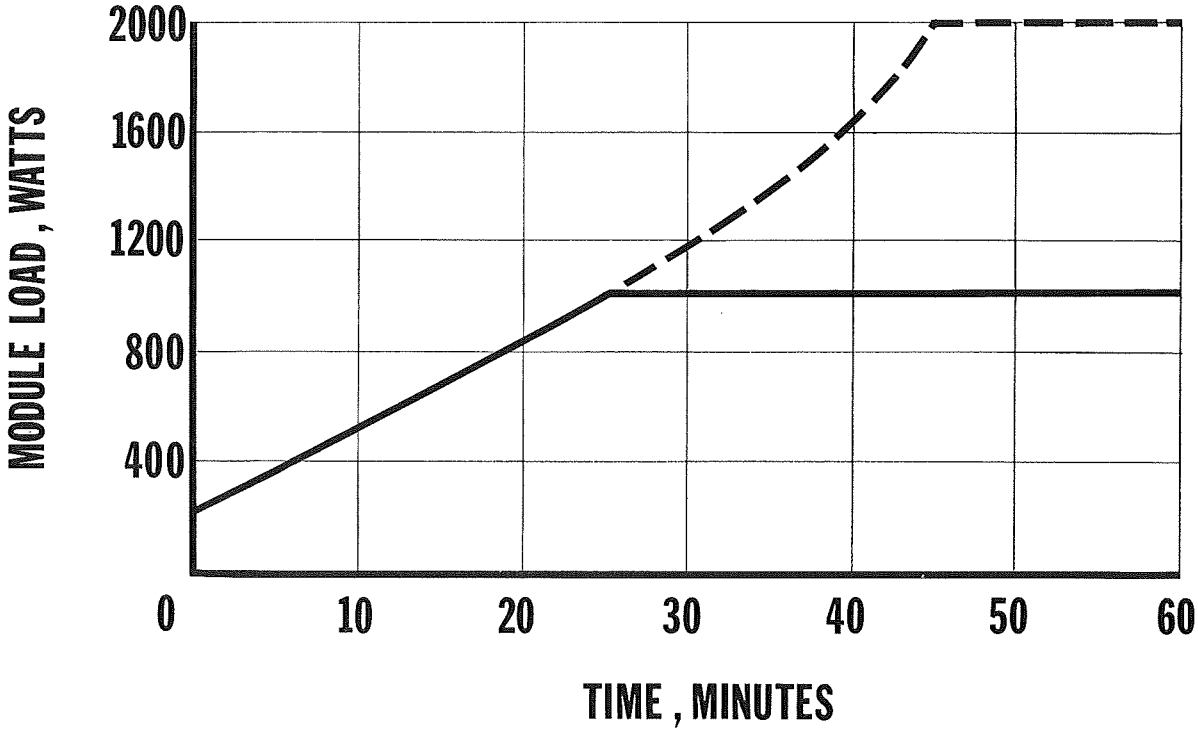
ELECTRICAL OUTPUT LIMIT	WARM UP TIME, MINUTES
27.5 VOLTS	59
100 AMPERES	26.5
250 AMPERES	6.5



REF: NAS 8-2695-OPR-1203

BOOTSTRAP CAPABILITY

PRACTICAL EXAMPLE



ASSUMPTIONS:
1. CONSTANT BUS VOLTAGE OF 28 VOLTS
2. CONSTANT BUS LOAD OF 2 KW
3. FUEL CELL BAY AMBIENT - 70°F
4. FUEL CELL HEATERS NOT USED

- NO EXTERNAL POWER REQUIRED TO BRING COLD STORAGE FUEL CELL INTO OPERATION

- PROVIDES ABILITY TO BRING COLD MODULE TO FULL POWER CAPABILITY IN VERY LITTLE TIME WITH NO EXTERNAL POWER

IN-SPACE START/STOP

TEST RESULTS

- 41 DAILY CYCLES ; 14 HR ON - 10 HR OFF WITHOUT DETRIMENTAL EFFECTS

- CELL CAVITIES NEED NOT BE FILLED WITH INERT GAS DURING STANDBY OR SHUTDOWN

- STACK MAY BE HELD AT OPERATING TEMPERATURE WITHOUT AFFECTING PERFORMANCE

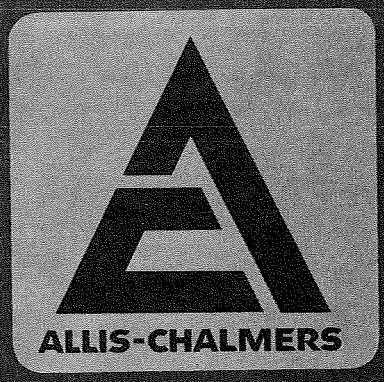
- DEMONSTRATED CAPABILITY ON 200 WATT FUEL CELL SYSTEM FLOWN ON TITAN III-C IN NOVEMBER 1966

REFERENCE: NAS 8-2696- QPR- 1203

IN-SPACE START/STOP

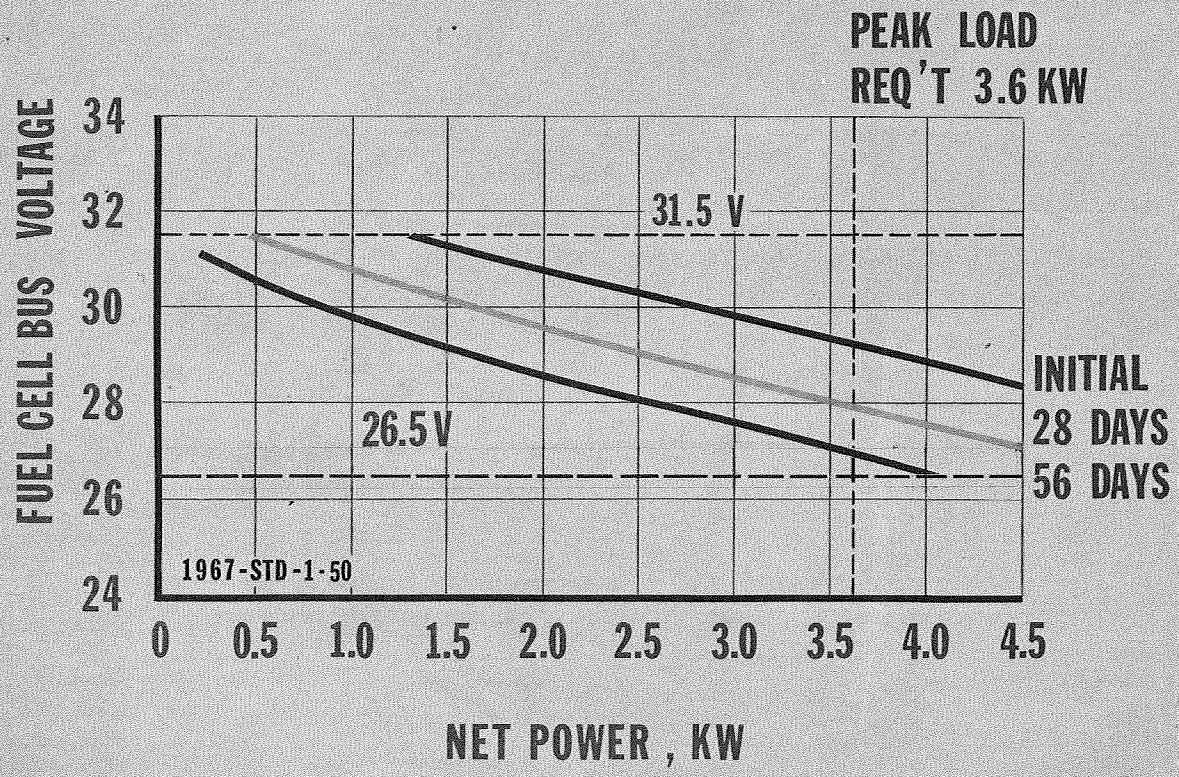
SIGNIFICANCE

- ILLUSTRATES COMPATIBILITY WITH HYBRID SOLAR PANEL POWER SYSTEM
- PROVIDES IN-SPACE STARTUP/SHUTDOWN MODE
- DEMONSTRATES FEASIBILITY OF ONE MODULE POWER DOWN MODE
- ALLOWS MINIMUM POWER TO BE ESTABLISHED BY RADIATOR FREEZE-UP, NOT THE FUEL CELL
- LOWER WEIGHT FOR IN-SPACE START MODE
- ALLOWS LONG TERM HOT STANDBY MODE



AAP ELECTRICAL POWER SYSTEM PERFORMANCE

SYSTEM ELECTRICAL PERFORMANCE

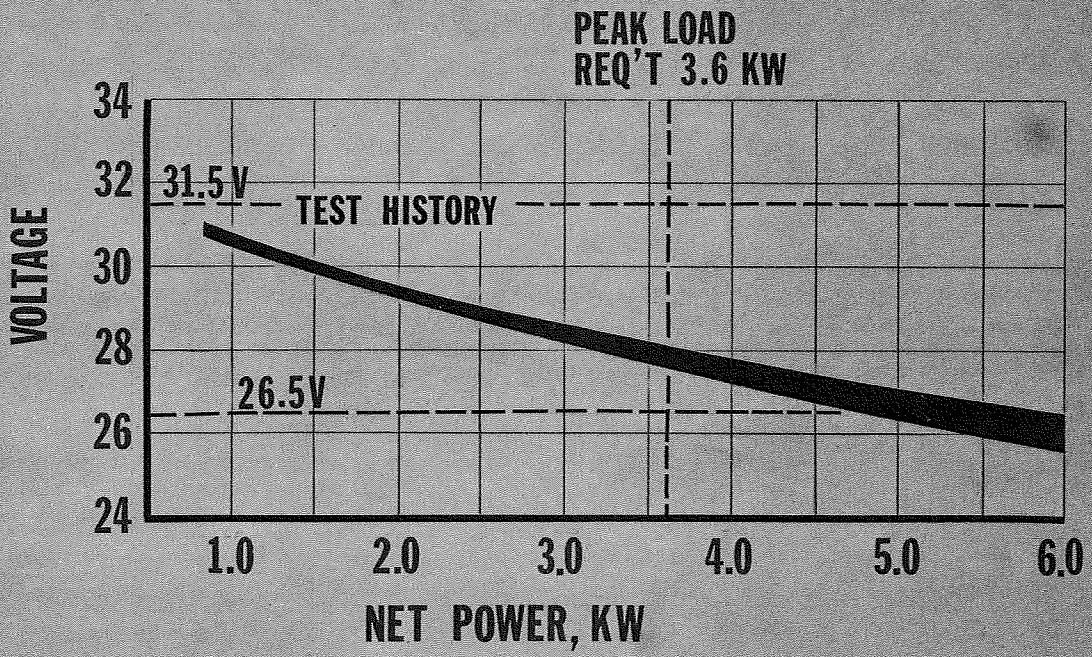


NOTE:

- 3 MODULE SYSTEM
- 32 SECTION MODULES

DEMONSTRATED SYSTEM PERFORMANCE

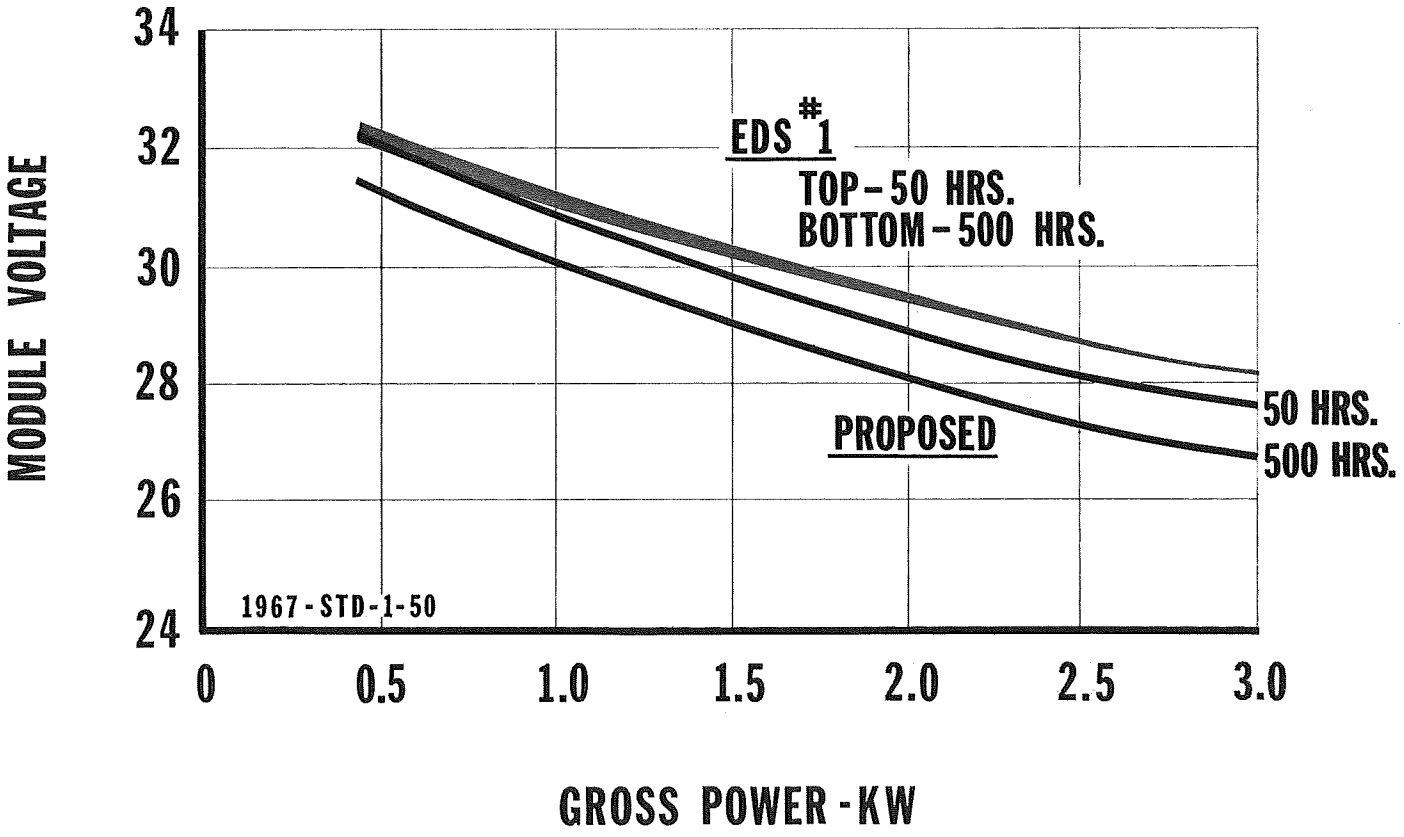
AT 56 DAYS



NOTES:

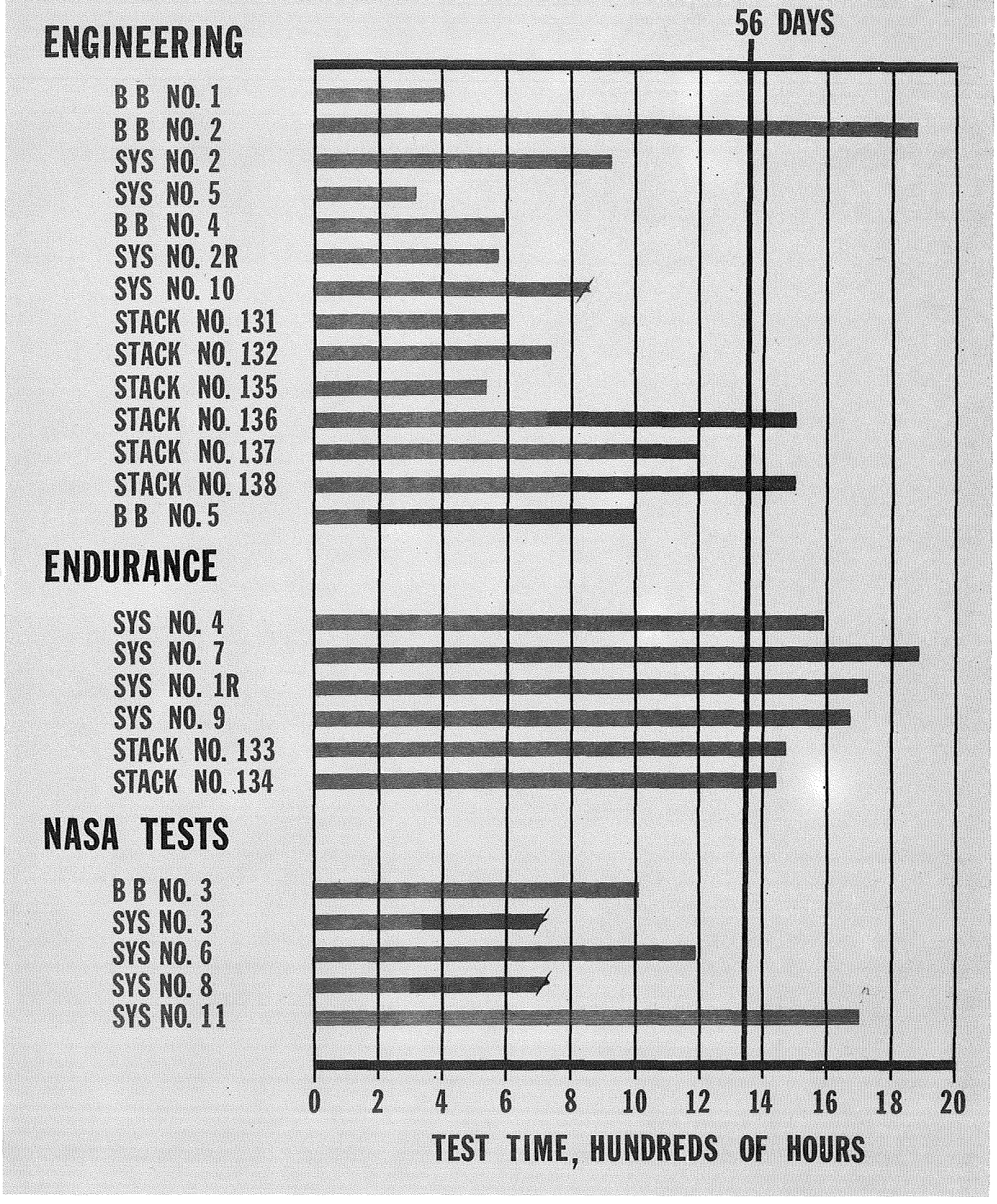
- 3 MODULE SYSTEM, 32 SECTIONS
- TEST HISTORY BASED UPON SYSTEMS 9,11 & 1R

EDS #1 ELECTRICAL PERFORMANCE

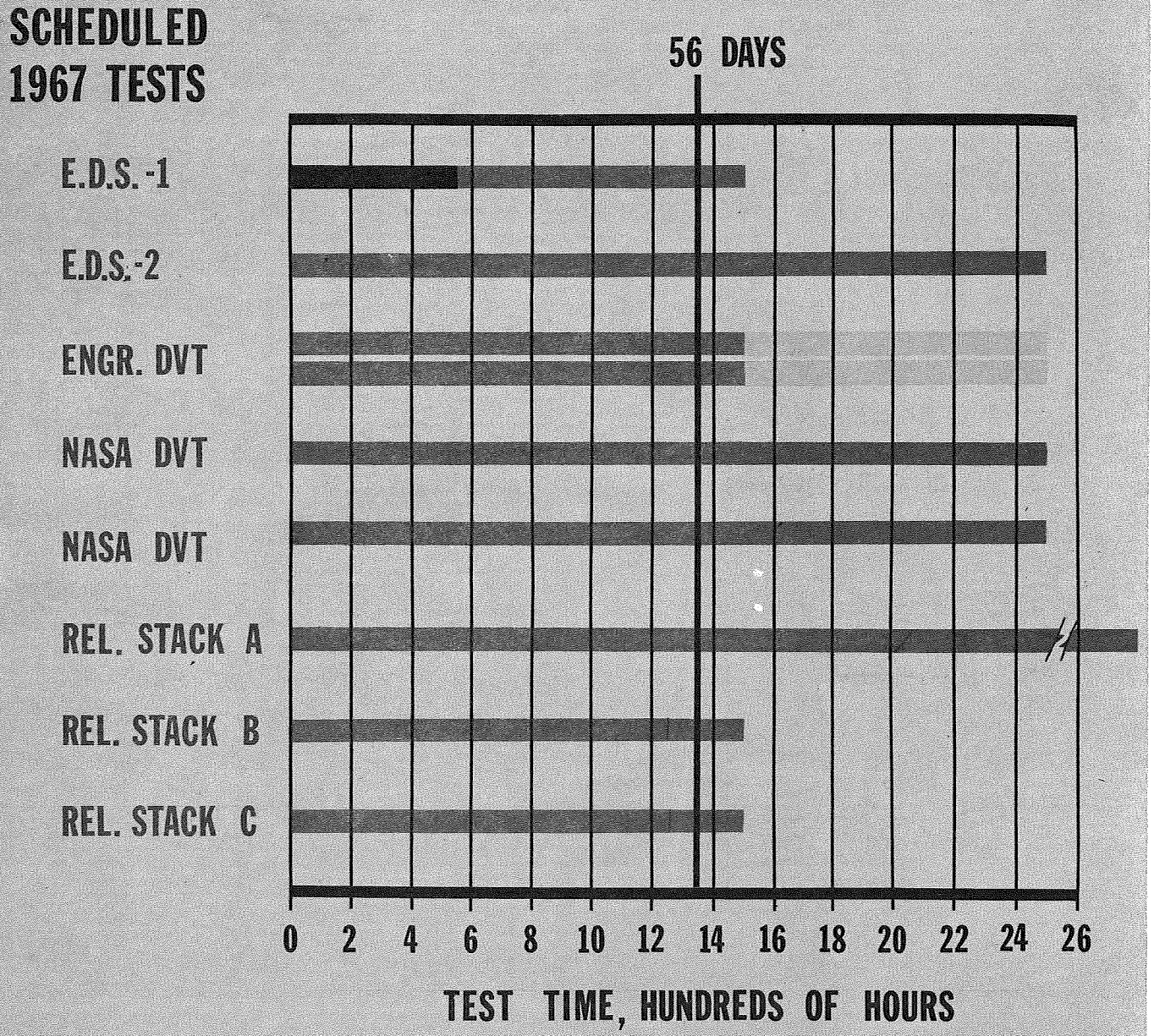


NOTE: SINGLE MODULE , 32 SECTIONS

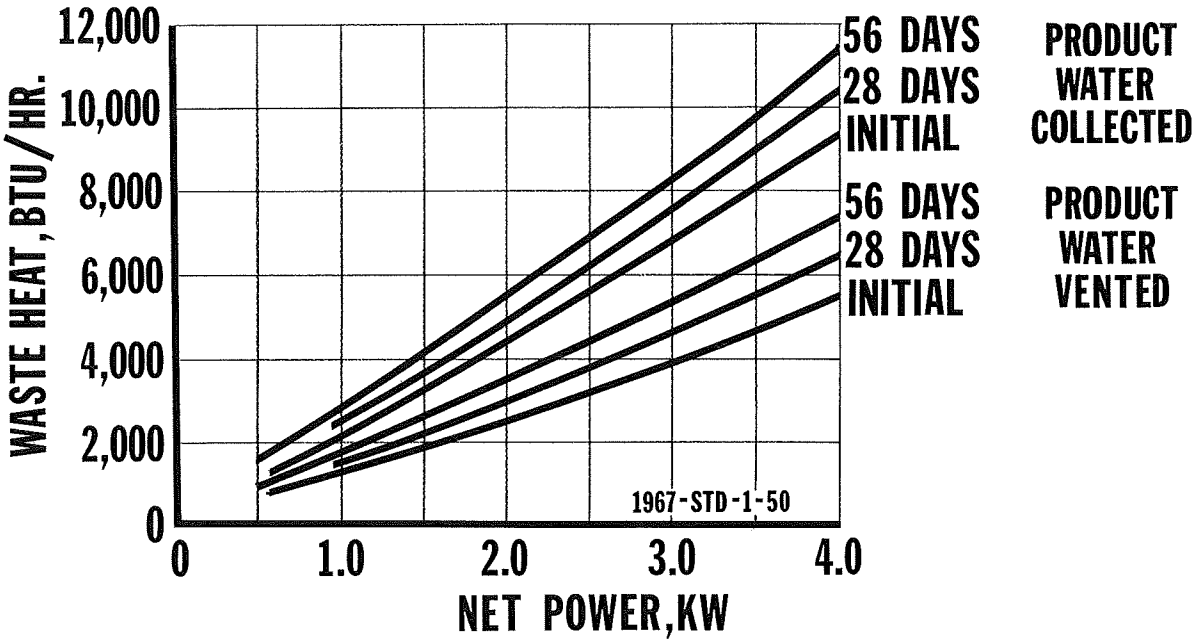
NASA HISTORY: TESTING



NASA HISTORY: TESTING



SYSTEM THERMAL PERFORMANCE

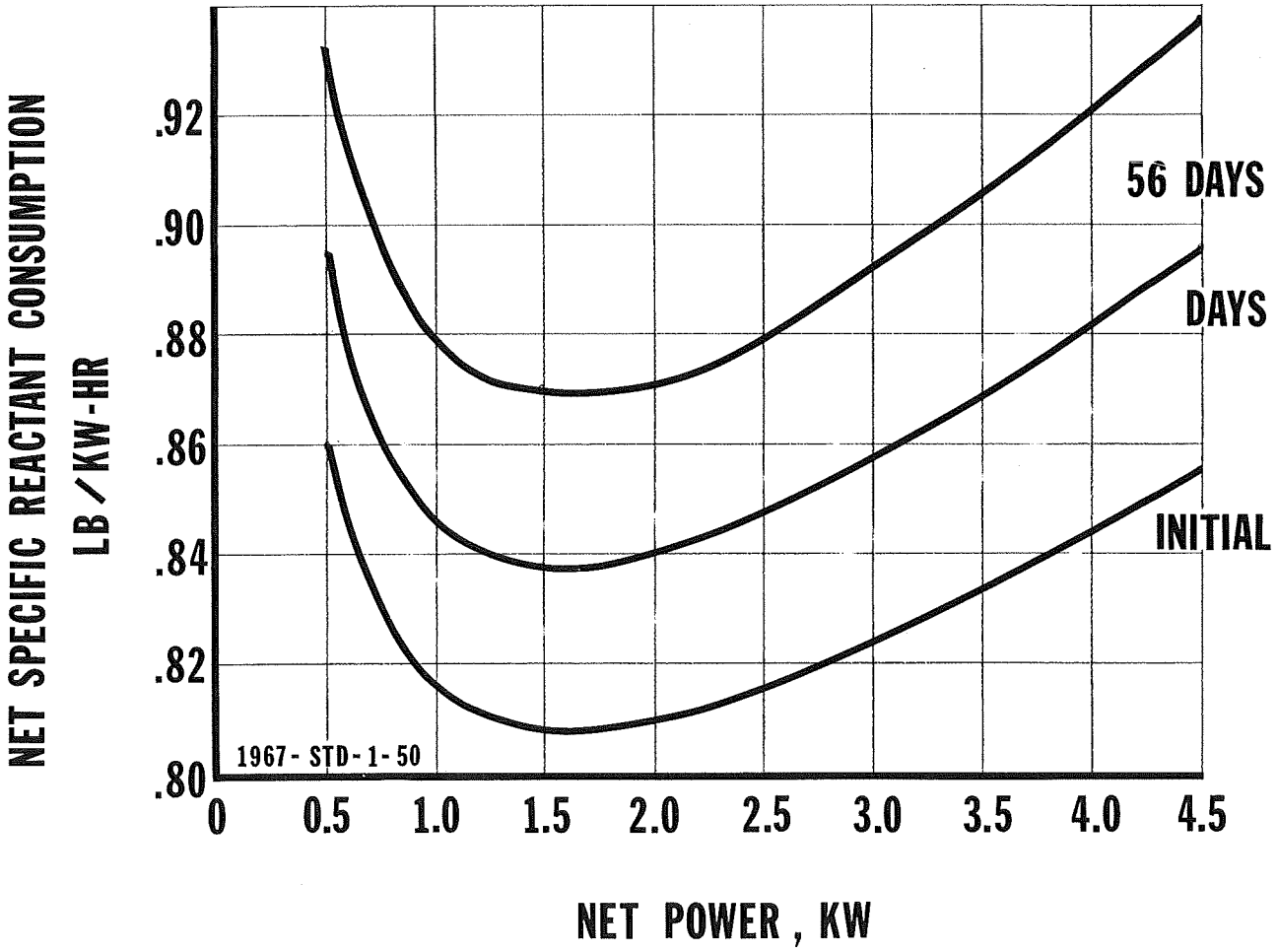


NOTE:

A. 3 MODULE SYSTEM

B. 32 SECTION MODULES

SYSTEM
REACTANT CONSUMPTION



NOTE:

- 3 MODULE SYSTEM
- 32 SECTION MODULES

OPERATION

START UP

1. START/STOP SWITCH TO START
2. WHEN STACK IS AT TEMPERATURE, OPEN REACTANT INLET VALVES
3. CONNECT TO BUS A, B OR BOTH

OPERATION

1. ALL AUTOMATIC CONTROL; NO MANUAL CONTROL NECESSARY

SHUTDOWN

1. STAND-BY; READY FOR IMMEDIATE RE-USE
    - A. DISCONNECT FROM BUS
2. STORAGE; IN FLIGHT
    - A. CLOSE INLET REACTANT VALVES
    - B. DISCONNECT FROM BUS
    - C. PLACE START/STOP SWITCH IN STOP POSITION

SALIENT PERFORMANCE FEATURES

- AUTOMATIC OPERATION
- START/RESTART CAPABILITY IN SPACE
- FAST, SIMPLE START UP & SHUTDOWN
- NO CATASTROPHIC POWER SYSTEM FAILURE MODES
- INSTANTANEOUS TRANSIENT RESPONSE
- INSENSITIVE TO SERVICE & CONTROL MALFUNCTIONS
- NO POWER MANAGEMENT REQUIRED FOR VOLTAGE REGULATION
- WATER RECOVERY INDEPENDENT OF POWER PRODUCTION
- MANUAL OVERRIDE CAPABILITY
- LIFE CAPABILITY TO 2500 HOURS
- INHERENTLY RUGGED
- UNAFFECTED BY FREEZING
- POTABLE PRODUCT WATER

FUEL CELL MODULE WEIGHT

MODULE ELEMENT	WEIGHT
STACK	78.0
MCS	25.0
COOLANT PUMP, ACCUMULATOR & VALVES	5.5
TCCS	21.7
RCCS	7.8
EMCA	5.0
MOUNTING BRACKET	7.5
CABLE HARNESS	4.0
THERMAL INSULATION	2.0
MISC. HARDWARE	5.0
TOTAL	161.5 LBS.

CSM RETROFIT ANALYSIS

RETROFIT STUDIES PERFORMED

- AVAILABILITY
- PHYSICAL INTERFACE
- SYSTEM WEIGHT
- CONTROL PANEL
- INSTRUMENTATION
- GSE

SYSTEM WEIGHT

ESTIMATED WEIGHT OF EXISTING POWER SYSTEM 745 LBS

ALLIS CHALMERS POWER SYSTEM

3 FUEL CELL MODULES 484.5 LB

BAY IV MOUNTING BRACKET 10.5 LB

SUB TOTAL 495 LBS

NET WEIGHT SAVINGS 250 LBS

REACTANT CONSUMPTION COMPARISON

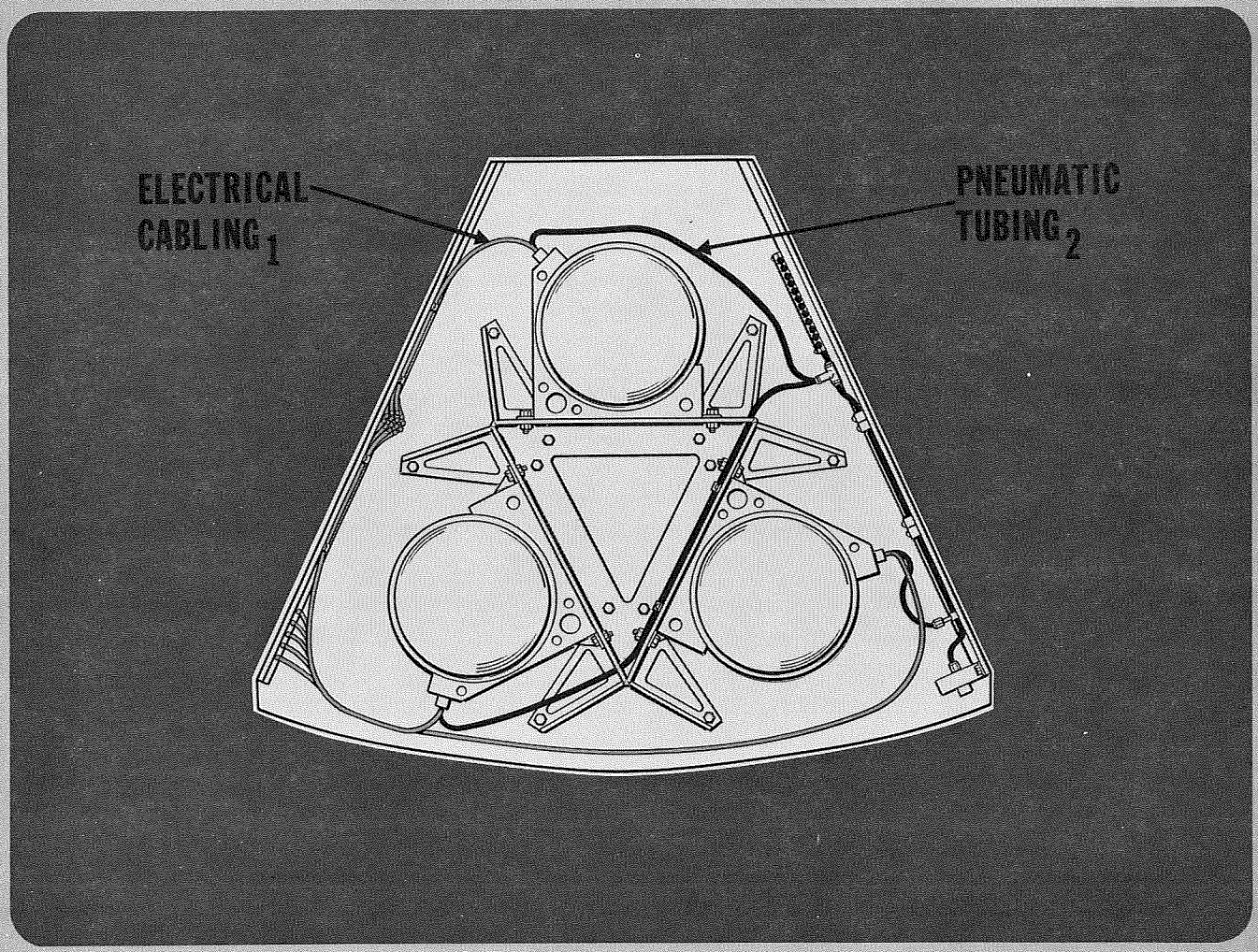
2.67 KW NET FOR 56 DAYS
3 MODULE SYSTEM

PRESENT SYSTEM 3005 LBS

ALLIS-CHALMERS SYSTEM 2933 LBS

FUEL SAVINGS 72 LBS

PHYSICAL INTERFACE
CABLING & PNEUMATIC



NOTE:

1. NO CHANGE REQUIRED
2. NO CHANGE TO SPACECRAFT, REROUTING FROM COMPARTMENT INTERFACE TO FUEL CELLS

CONTROL PANEL SWITCHES

EXISTING DESIGNATION	NEW DESIGNATION	CABLING OR SWITCH CHANGE
• REACTANT INLET-3 SW	SAME	NO CHANGE
• REACTANT PURGE-3 SW		NOT REQ'D [1]
• BUS A & B CONNECT-6 SW	SAME	NO CHANGE
• FUEL CELL PUMP-3 SW		NOT REQ'D [2]
• IN-LINE HEATER-3 SW	START/STOP-3 SW	NO CHANGE
• FUEL CELL INDICATOR SEL.-1 SW	SAME	NO CHANGE
• D C INDICATOR SEL.-1 SW	SAME	NO CHANGE
• EMERGENCY BYPASS-3 SW	SAME	NO CHANGE

NOTE: OPTIONAL FEATURES

1. MANUAL PURGE OVERRIDE - NO CHANGE REQ'D
2. AVAILABLE

CONTROL PANEL INSTRUMENTATION

METERS

EXISTING DESIGNATION	NEW DESIGNATION	INSTRUMENT CHANGE
DC VOLTS	SAME	NO CHANGE
DC AMPS	SAME	NO CHANGE
H_2 FLOW	SAME	NO CHANGE
O_2 FLOW	SAME	NO CHANGE
MODULE TEMP-SKIN	—	NOT REQUIRED[1]
MODULE TEMP-COND. EXH.	MODULE TEMP.	NO CHANGE

FLAG INDICATORS

EXISTING DESIGNATION	
H_2 PRESSURE - HI; 1 - SEL.	NO CHANGE
O_2 PRESSURE - HI; 1 - SEL.	NO CHANGE
N_2 PRESSURE - HI; 1 - SEL.	NOT REQUIRED
RADIATOR TEMP. LOW; 1 - SEL.	NO CHANGE
PH - HI; 1 - SEL.	NOT REQUIRED[2]
FC REACTANT - OPEN/CLOSED; 3 - IND.	NO CHANGE
FC RAD. BY PASS - NORMAL/EMERG; 3 - IND.	NO CHANGE
MAIN BUS A - ON/OFF; 3 - IND.	NO CHANGE
MAIN BUS B - ON/OFF; 3 - IND.	NO CHANGE

NOTE:

1. OPTION TO USE FOR H_2O CAVITY PRESSURE
2. MAY USE IF DESIRED

GROUND INSTRUMENTATION

TELEMETRY

EXISTING DESIGNATION	NEW DESIGNATION	CHANGE REQ'D
DC BUS VOLTAGE		
BUS A	SAME	NO CHANGE
BUS B	SAME	NO CHANGE
DC CURRENT OUT	SAME	NO CHANGE
SKIN TEMPERATURE	STACK TEMP.	SCALE CHANGE
COND. EXIT TEMP.	CAVITY PRESS.	SCALE CHANGE
H_2 PRESSURE	SAME	NO CHANGE
O_2 PRESSURE	SAME	NO CHANGE
N_2 PRESSURE	He PRESS.	NO CHANGE
H_2 FLOW	SAME	NO CHANGE
O_2 FLOW	SAME	NO CHANGE
RAD. OUT TEMP.	SAME	NO CHANGE
BUS A DISCONNECT	SAME	NO CHANGE
BUS B DISCONNECT	SAME	NO CHANGE
FUEL CELL SHUT-OFF	SAME	NO CHANGE

GROUND INSTRUMENTATION

CHECKOUT SIGNALS

EXISTING DESIGNATION	NEW DESIGNATION	CHANGE REQ'D
NON-ESSENTIAL BUS VOLTAGE	SAME	NO CHANGE
DC VOLTAGE BUS A	SAME	NO CHANGE
DC VOLTAGE BUS B	SAME	NO CHANGE
DC CURRENT OUT	SAME	NO CHANGE
BUS A DISCONNECT EVENT	SAME	NO CHANGE
BUS B DISCONNECT EVENT	SAME	NO CHANGE
PURGE VALVE OPERATION EVENT, H_2 & O_2	SAME	NO CHANGE

UMBILICAL PRE-FLIGHT STATUS		
FUEL CELL DC VOLTAGE	SAME	NO CHANGE
INLINE HEATER ON	—	NOT REQUIRED
INLINE HEATER OFF	—	NOT REQUIRED
DC POWER DEADFACE SWITCH ON-OFF EVENT	—	NOT REQUIRED

GROUND SUPPORT EQUIPMENT

EXISTING EQUIPMENT	MODIFICATIONS REQUIRED
GLYCOL FILL UNIT	NO CHANGE
F.C. HEATER POWER SUPPLY	NOT REQUIRED
LOAD BANK	NO CHANGE
AUTOMATIC CHECKOUT EQUIPMENT	MINOR CHANGE 1
REACTANT & PURGE GAS SUPPLY	NO CHANGE
WATER REMOVAL SYSTEM	MINOR CHANGE 2
HANDLING EQUIPMENT	NO CHANGE

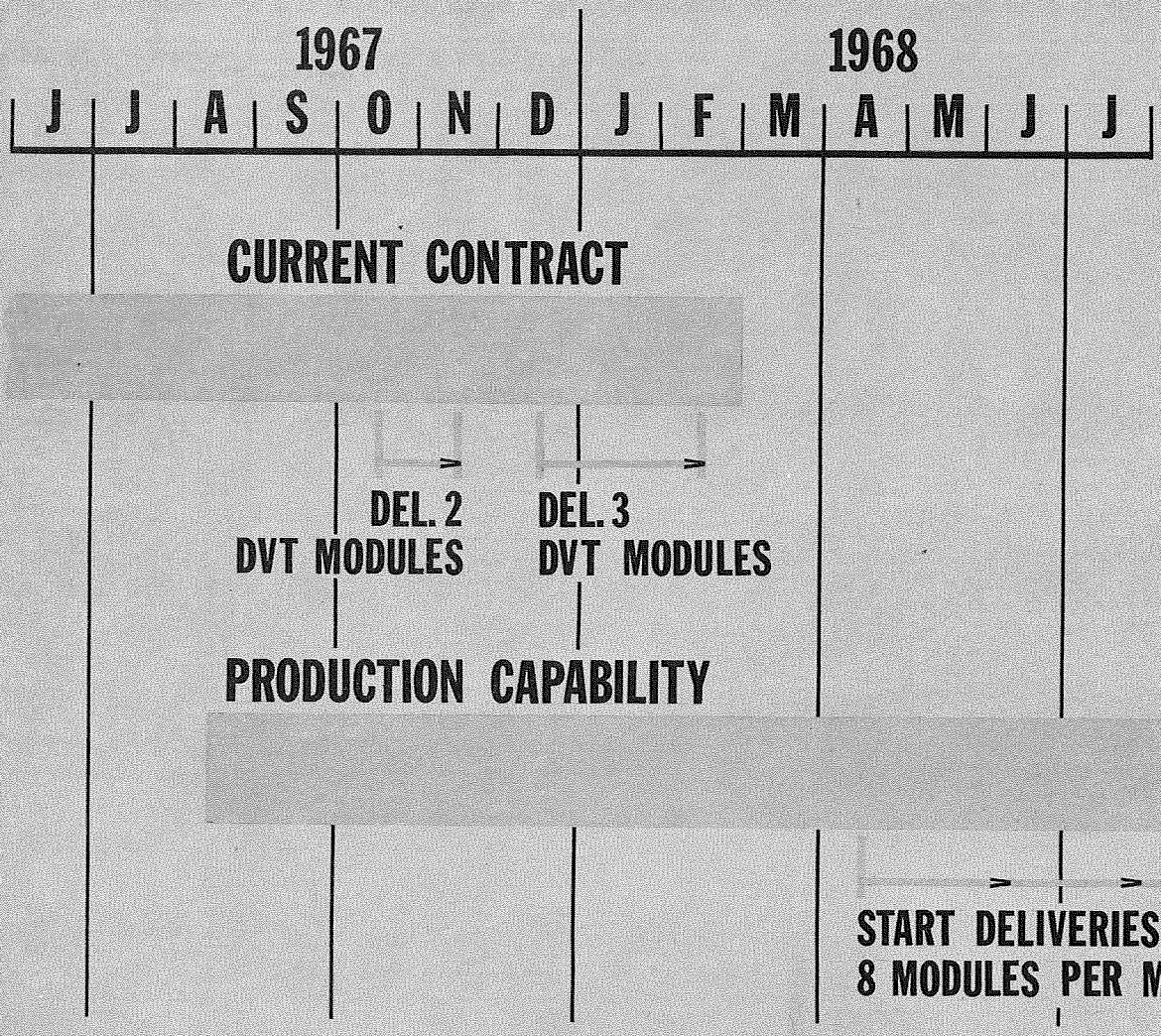
NOTE:

1 REDESIGNATION ON SOME FUNCTIONS

2 REPLUMBING FOR USE OF VACUUM PUMP

PROGRAM SUPPORT CAPABILITIES

HARDWARE AVAILABILITY



AAP PROGRAM SCHEDULE

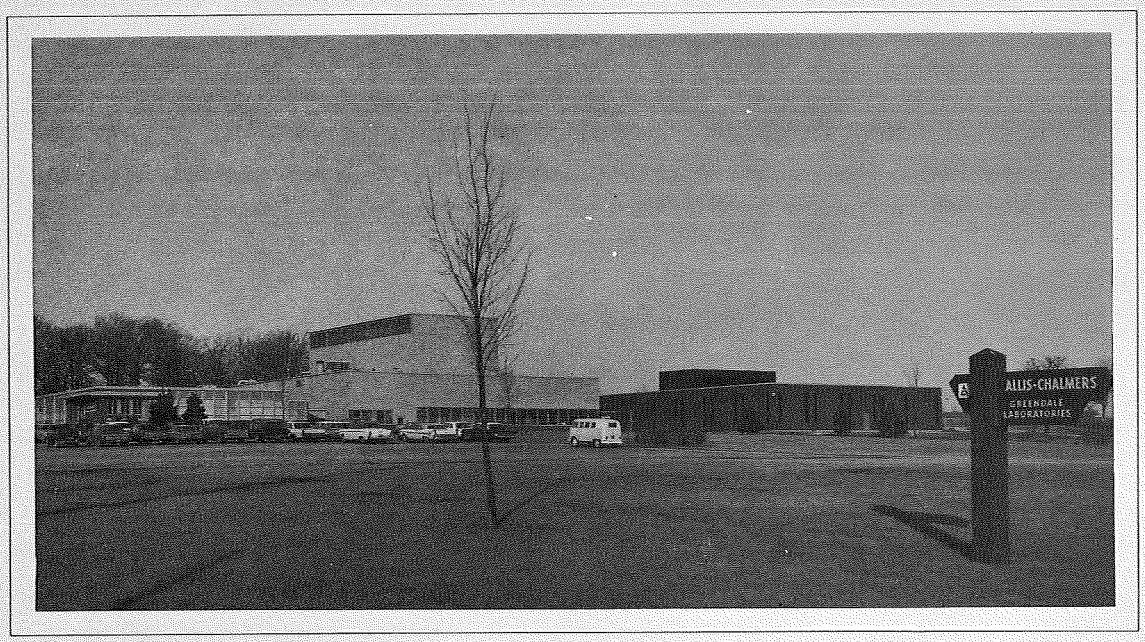
MISSION-A

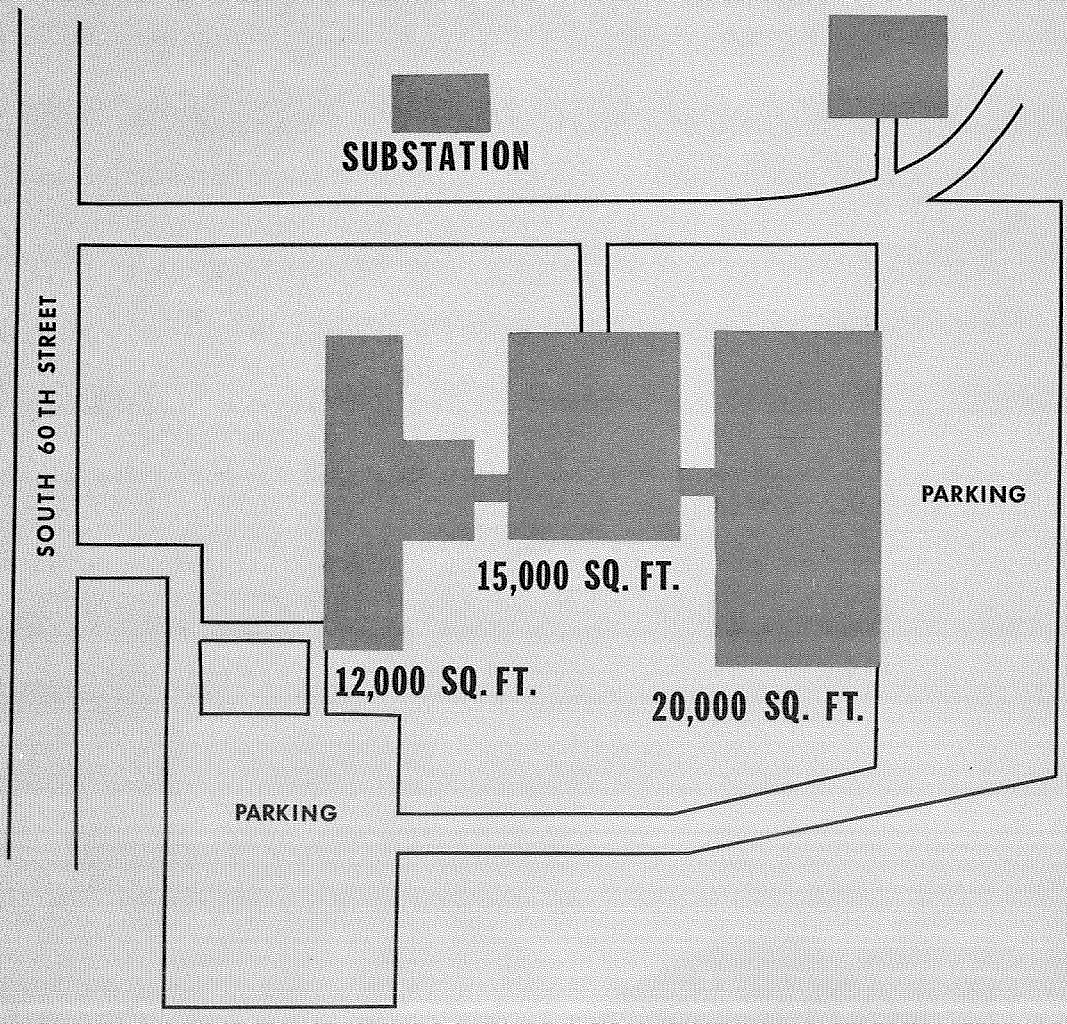
HDW. REQ'D. – AUG., 1968 FLIGHT – FEB., 1969

MISSION-B

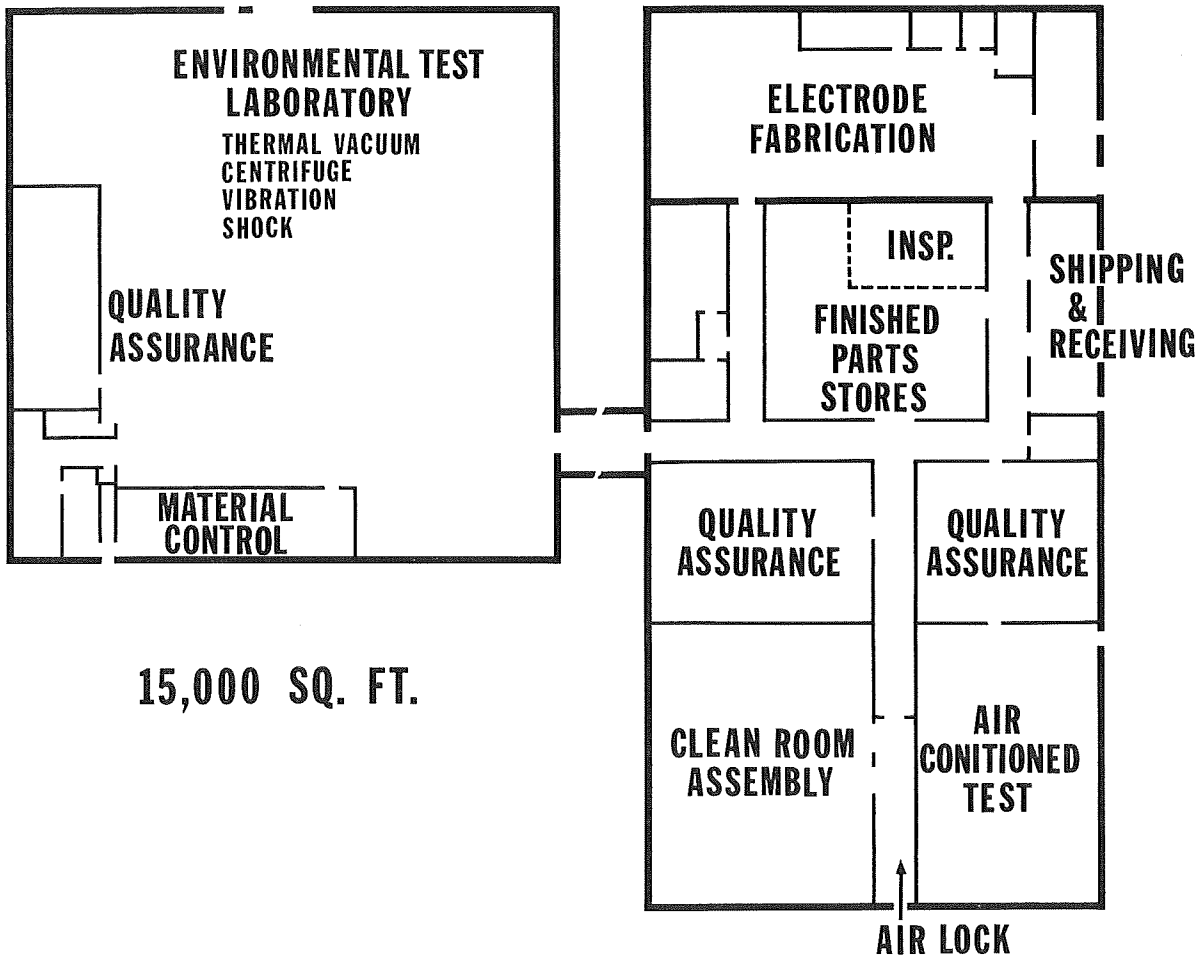
HDW. REQ'D. – FEB., 1969 FLIGHT – AUG., 1969

THE GREENDALE FACILITIES





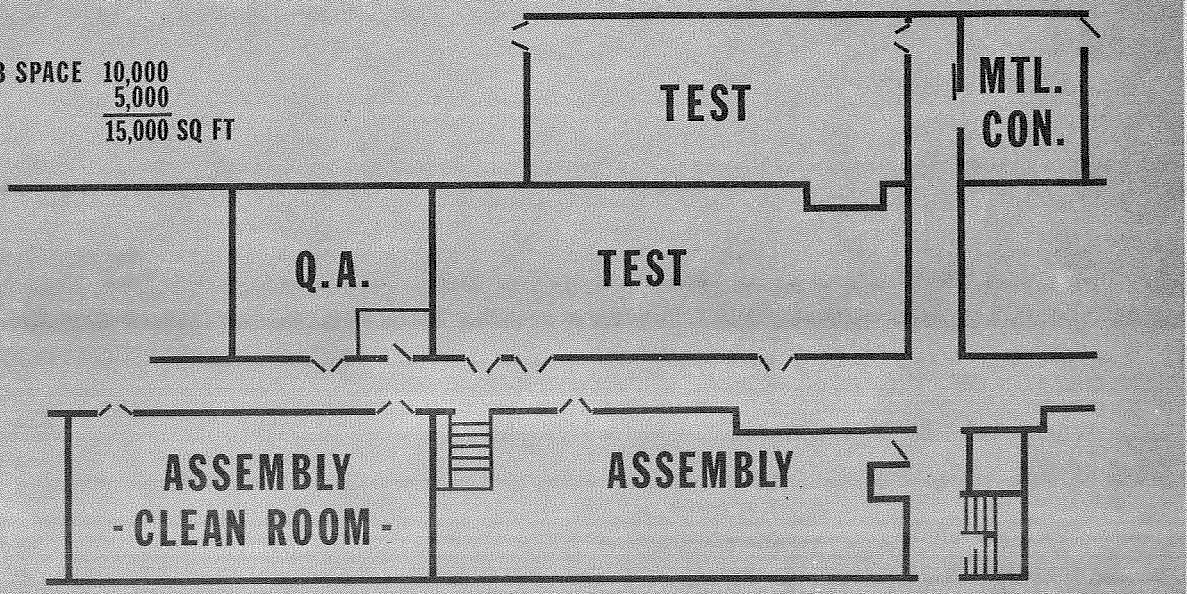
GREENDALE
ASSEMBLY & TEST FACILITIES



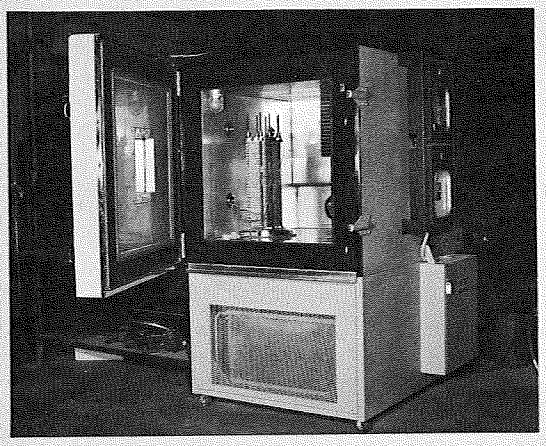
THE WEST ALLIS PLANT

OFFICE SPACE 4,700 SQ FT

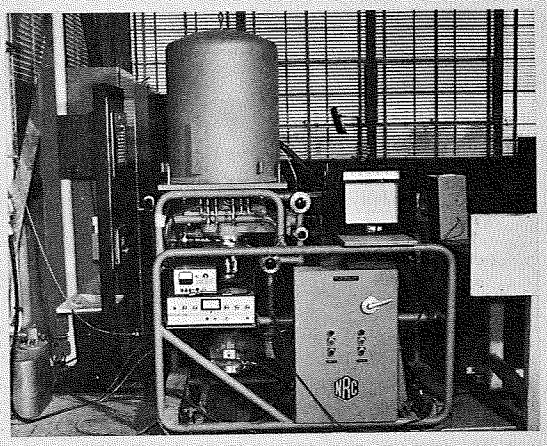
LAB SPACE 10,000
5,000
15,000 SQ FT



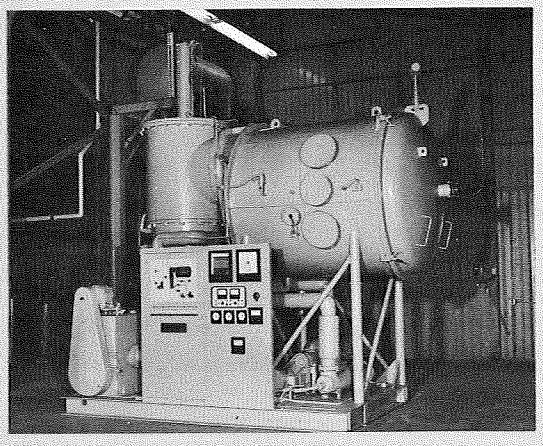
FACILITIES



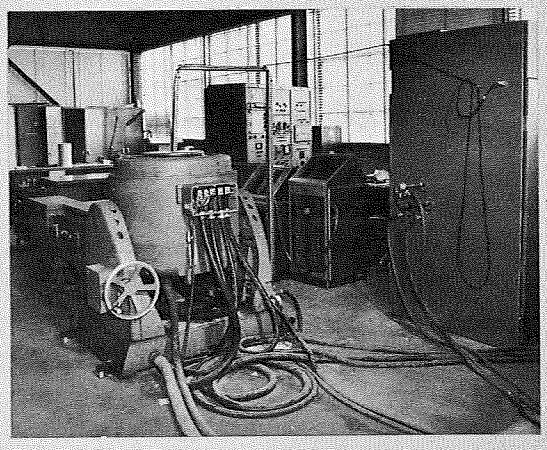
TEMPERATURE CHAMBER



VACUUM CHAMBER



THERMAL-VACUUM CHAMBER



VIBRATION EQUIPMENT

QUALITY ASSURANCE

DEVELOPMENT SUPPORT ACTIVITIES

GUIDELINES- NPC 200-2, NPC 200-3, NPC 250-1

IMPLEMENTED ACTIVITIES

- DESIGN RELEASE
- CHANGE DOCUMENTATION
- MATERIAL CONTROL & TRACEABILITY
- ASSEMBLY HISTORY LOGS
- TEST PROCEDURES
- TEST LOGS & DATA RECORDS
- INSTRUMENT CALIBRATION & CONTROL
- UNSATISFACTORY CONDITION REPORTING
- FAILURE INVESTIGATION & ANALYSIS
- VENDOR LIAISON

RELIABILITY EFFORTS

- FAILURE EFFECTS ANALYSIS
- RELIABILITY ESTIMATES

MAINTAINED INFORMATION FILES

- NASA & MIL SPECS & STDS
- NASA DESIGN GUIDELINES

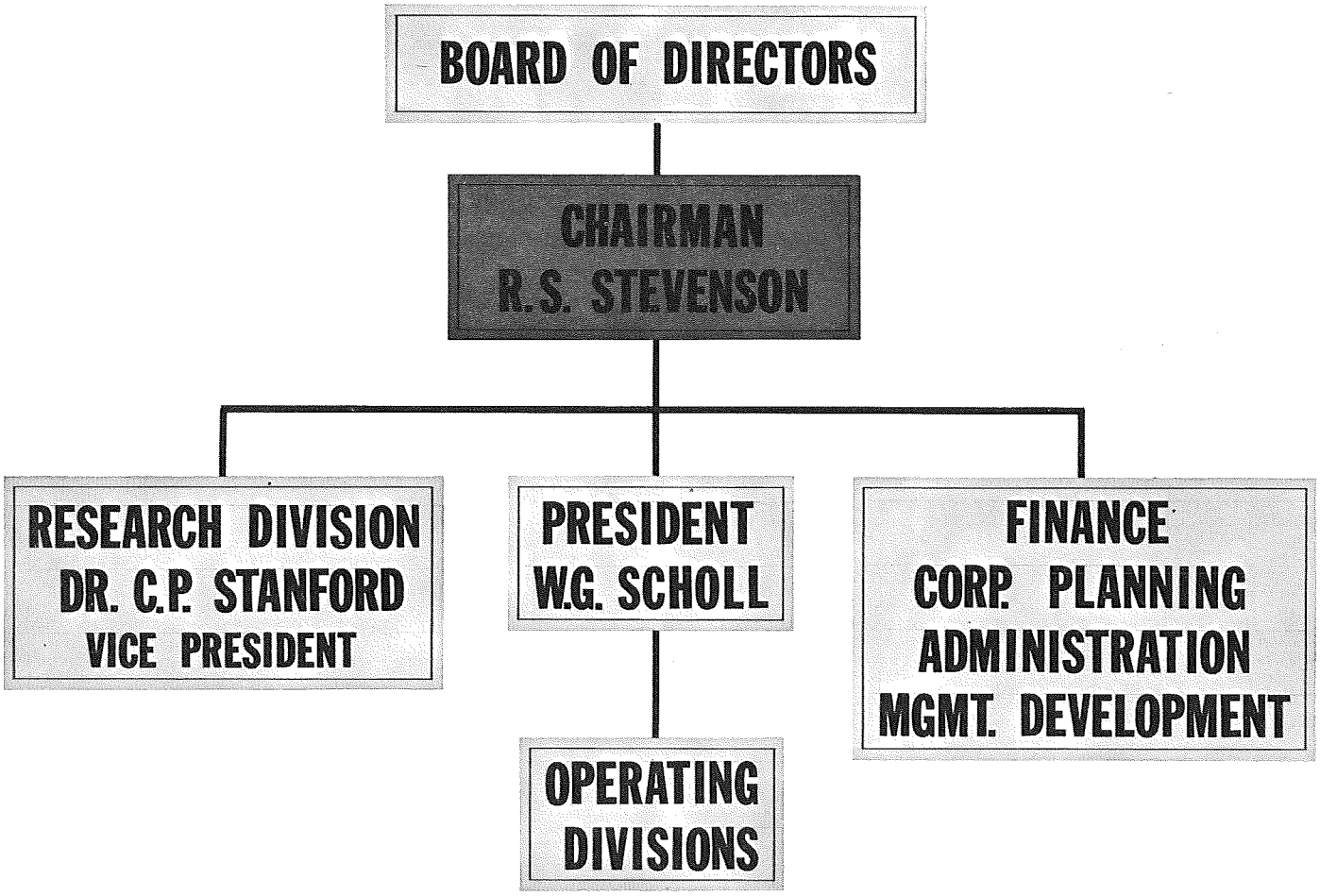
QUALITY ASSURANCE

CURRENT PROGRAM STATUS - NAS 9-6737

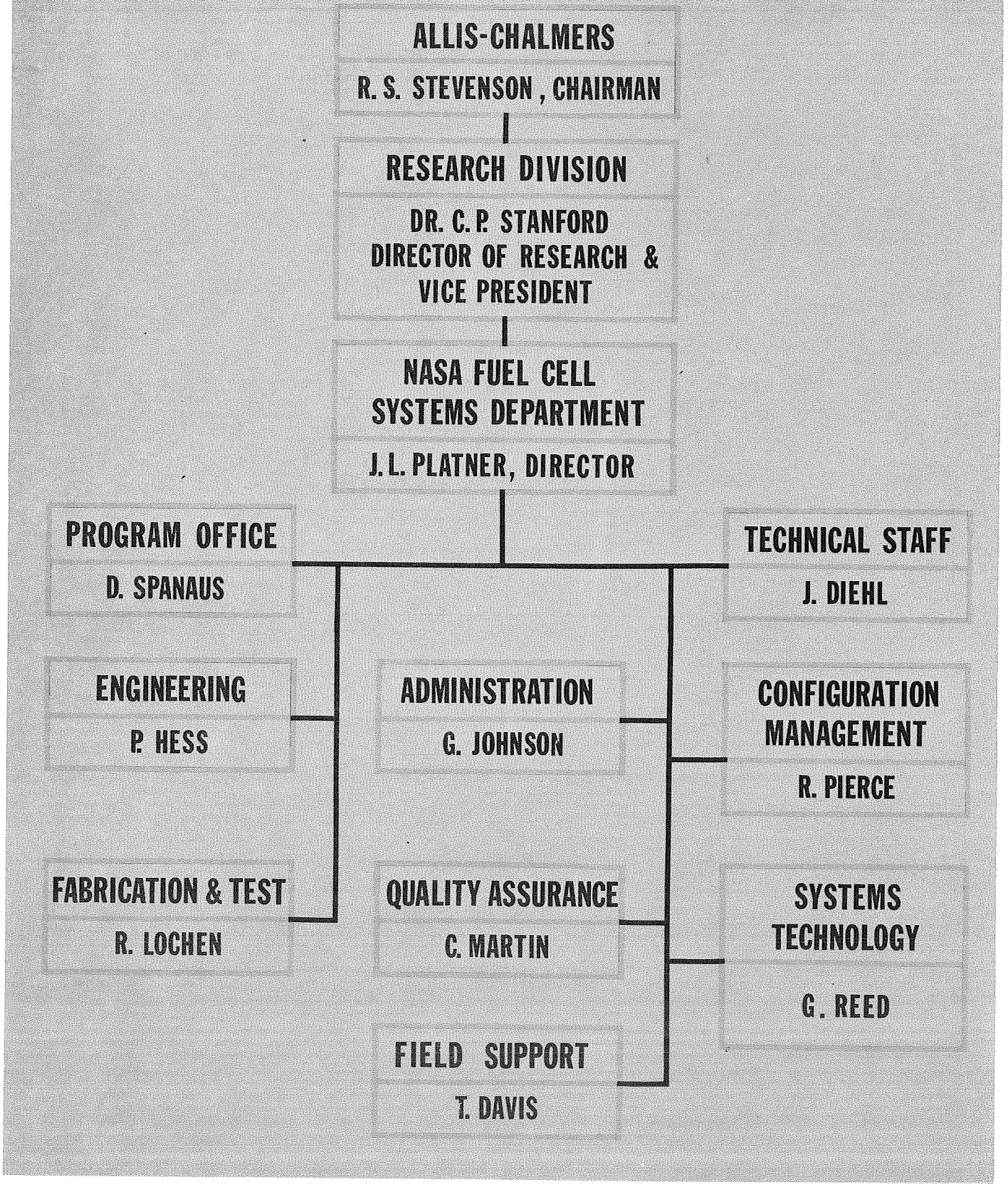
REQUIREMENTS	IMPLEMENTATION STATUS
NPC 200-3 & NPC 200-2 SEC. 8	• BASICS IMPLEMENTED • DOCUMENTED BY OCT 1967
MSC-QA MONITOR	• ESTABLISHED
DECAS SURVEILLANCE	• ESTABLISHED
RELIABILITY	• COMMUNICATIONS ESTABLISHED -ASD AT MSC -APIC AT MSFC • APPROVED SOURCE LISTS • UPDATED FEA & REL. ESTIMATES • FORMAL DESIGN REVIEWS
TRAINING & CERTIFICATION	• SOLDERING SCHOOL IMPLEMENTED • WELDER RECERTIFICATION
FACILITY CLEAN ROOM COMPONENT TEST Q.A. LABS	 • CONTROL ESTABLISHED • CONSOLE FIN. MAY 1967 • MANNED & OPERATING
PERSONNEL	• 16% OF DIRECT

● FULLY APPROVED QA PROGRAM-OCTOBER 1967

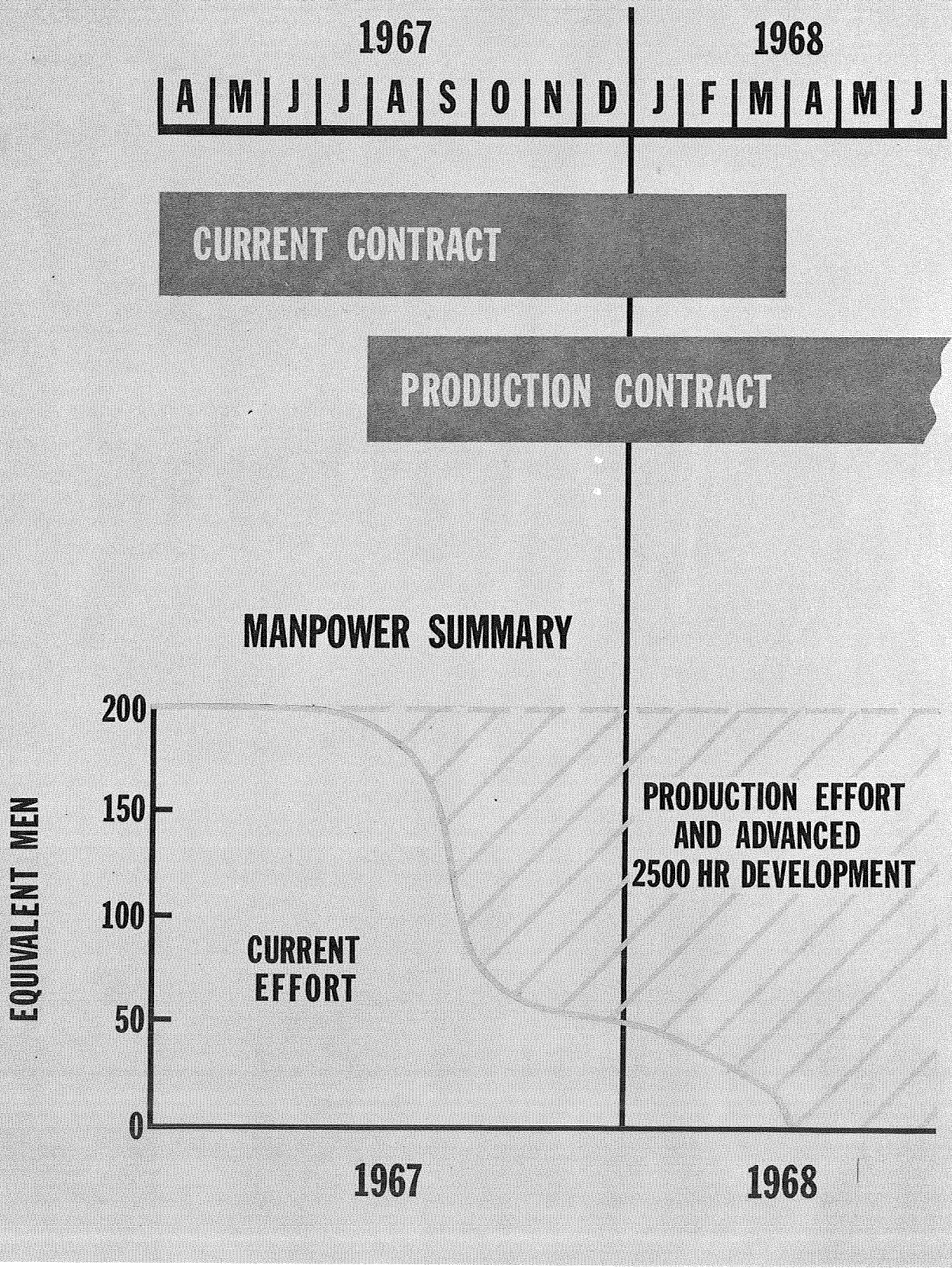
ALLIS-CHALMERS
CORPORATE STRUCTURE

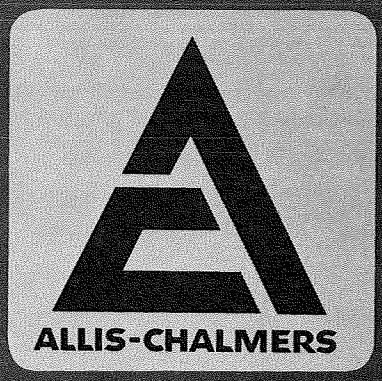


MANAGEMENT


ALLIS-CHALMERS
R. S. STEVENSON, CHAIRMAN
RESEARCH DIVISION
DR. C. P. STANFORD
DIRECTOR OF RESEARCH & VICE PRESIDENT
NASA FUEL CELL SYSTEMS DEPARTMENT
J. L. PLATNER, DIRECTOR
PROGRAM OFFICE
D. SPANAUS
TECHNICAL STAFF
J. DIEHL
ENGINEERING
P. HESS
ADMINISTRATION
G. JOHNSON
CONFIGURATION MANAGEMENT
R. PIERCE
FABRICATION & TEST
R. LOCHEN
QUALITY ASSURANCE
C. MARTIN
SYSTEMS TECHNOLOGY
G. REED
FIELD SUPPORT
T. DAVIS

MANPOWER AVAILABILITY





SUMMARY

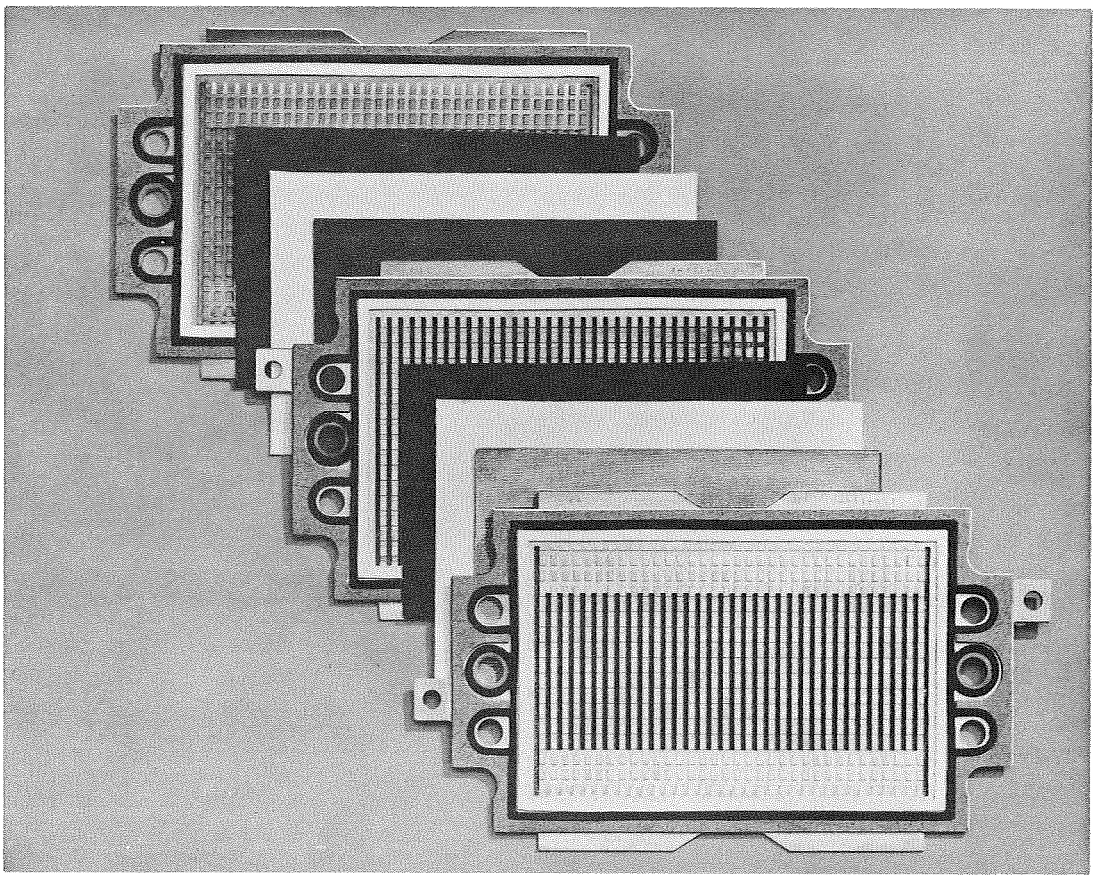
MAJOR BENEFITS

- HARDWARE AVAILABLE — JULY 1968
- PROVEN LIFE — 1500+HRS. DEMONSTRATED
  — 2500 HR. CAPABILITY
- PERFORMANCE — 12KW PEAK EMERGENCY
  — TRANSIENT RESPONSE
- WEIGHT SAVINGS — 250LB IN EPS
  — ADDITIONAL IN FUEL
- INTERCHANGEABLE — NO SPACECRAFT MODIFICATIONS
- COST SAVINGS — ADVANCED DESIGN WITH MINIMUM PERTURBATION

RECOMMENDATIONS

- VERIFICATION OF INTEGRATION CAPABILITY OF ALLIS-CHALMERS FUEL CELLS IN CSM FOR MISSIONS A & B...AND BEYOND
- IMPLEMENT OVERALL AAP SUPPORT ANALYSIS FOR OWS, ATM, APPS-A & B, LUNAR MODULE, LUNAR SURFACE OPER.
- INITIATE IMMEDIATELY PLANNING TO SUPPORT 1500 HR. QUALIFICATION AND PRODUCTION PROGRAMS
- EXTENT LIFE EVALUATION TO 2500 HRS.

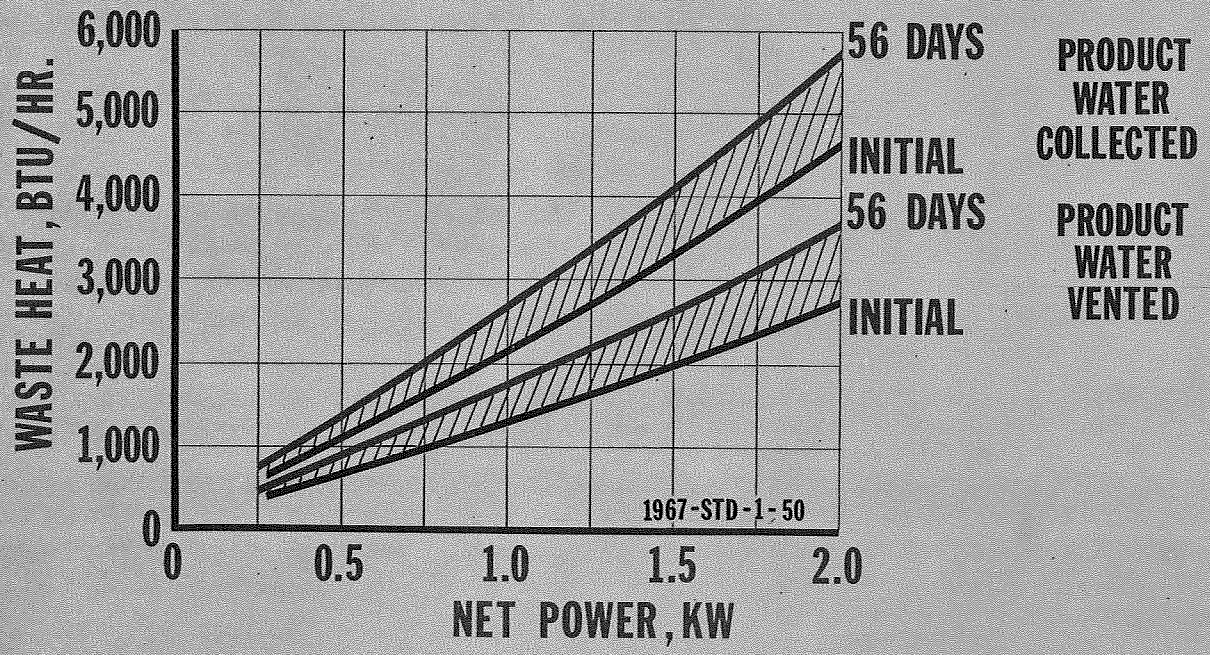
FUEL CELL CONSTRUCTION



AUTOMATIC CONTROLS

CONTROL	INPUTS	OUTPUTS
HEATER - REACTANT	- STACK TEMP. - START SIGNAL - REACT. OVER PRESS.	- HEATERS ON - READY SIGNAL - OPEN/CLOSE REACT. VALVES
PURGE	- MODULE CURRENT	- OPEN PURGE VALVE - 5 SEC.
COOLANT	- STACK TEMP.	- OPEN COOLANT VALVE
WATER CAVITY PRESSURE	- STACK TEMP. - CAVITY PRESS.	- OPEN MOISTURE REMOVAL VALVE
WATER RECOVERY		
- VENT	- PRESS. SWITCH	- OPEN/CLOSE VAPOR VENT VALVE
- PUMP	- LEVEL SWITCH	- OPERATE PUMP CONTROL VALVE

MODULE THERMAL PERFORMANCE



NOTE:

A. 50 WATTS PARASITIC POWER

B. SINGLE 32 SECTION MODULE